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Metallurgy Program

51

Division of Materials Research

Active Research and Equipment Grants

National Science Foundation

September 1, 1982

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Preface

The goal of this report is to provide you with a summary of all active NSF Metallurgy Program research and equipment grants. It is intended to help current and future materials research scientists, managers and administrators coordinate and plan research activities and expenditures in an effective manner. It is also hoped this report will serve as a guide to undergraduate students planning to continue on to graduate work in materials science. If you wish to obtain any additional information about a specific project, please contact directly the investigator(s) listed.

The following information is provided for each project: the title; name(s), departmental affiliation, institution and telephone number of the investigator(s); the current award amount in thousands of dollars, duration of support in months, type of award (i.e., for project 1, 85.8/12/3CR is $85,800 for 12 months as a three-year renewed continuing grant) and the effective date of the award. The key to the symbols used is given, as well as a breakout of areas of support, materials under study, and an alphabetical listing of the investigators and their affiliation.

Dr. Wayne Robertson (on leave from Rockwell International Science Center) served as Associate Director of the Metallurgy Program for part of fiscal year 1982. He returned to his home in California, and after a serious illness, passed away on July 12, 1982. Wayne's excellent contributions to the scientific/technical literature as a materials researcher, and his outstanding dedication, understanding, and professionalism in service to the scientific community as an NSF Program Officer will always be remembered.

During fiscal year 1983, I will be on Sabbatical Leave. The Metallurgy Program will be administered by Dr. Ronald Gibala (on leave from Case Western Reserve University) with the assistance of Dr. Lance Haworth (on leave from Wayne State University). Please contact either Ron or Lance if you need further information or assistance. They can be reached at (202)357-9789.

Lastly, the timely and accurate processing of all fiscal year 1982 Metallurgy Program transactions, and preparation of this year-end report would not have been possible without the assistance of our Program Secretary, Barbara Bailey. Her dedication and service to the materials community is greatly appreciated.

Robert J. Reynik
Director
Metallurgy Program

September 1, 1982

Key to Symbols

IUC: Industry/University Cooperative Research
CE: Creativity Extension
CONF: Conference
E: Equipment
R: Renewal

S: Supplement
2CN or 3CN: Two (or three) year new continuing grant
xy CN: xy months of new continuing grant
2CR or 3CR: Two (or three) year renewed continuing grant
xy CR: xy months of renewed continuing grant

Areas of Support

Conference: C1

Creep, Fatigue, Fracture: 8, 21, 27, 34, 50, 67, 69, 70, 76, 83, 101, 105, 108, 109, 113

Defects, Dislocation Dynamics: 9, 26, 31, 33, 36, 45, 54, 57, 63, 81, 104

Deformation Processing: 12, 13, 28, 40, 41

Environmental:
- a) Electrochemical (corrosion, oxidation, hydrogen attack): 4, 7, 14, 23, 42, 52, 55, 62, 78, 84, 93, 96, 99
- b) Erosion, Friction/Wear: 18, 51, 86, 111
- c) Hydrogen Embrittlement: 6, 35, 44, 58, 61, 73, 100

Equipment: E1 through E24

Interfaces:
- a) External Surfaces (structure, modification, properties): 20, 32, 39, 82, 103, 106, 115
- b) Grain Boundaries (structure, properties): 5, 11, 19, 56, 65, 72, 77, 90

Mechanical Behavior (general): 3, 10, 15, 49, 66, 87, 98, 110

Phase Equilibria: 16, 17, 46, 59, 60, 89, 112

Phase Transformations (order-disorder, nucleation and growth, spinodal decomposition, segregation, structural characterization, etc.): 1, 22, 24, 25, 29, 38, 53, 64, 71, 75, 79, 88, 91, 92, 95, 97, 102, 107, 114

Solidification: 2, 30, 37, 43, 47, 48, 68, 74, 80, 85, 94

1. Solid-Solid Nucleation

Current Award: 85.8/12/3CR
Effective Date: 1/1/82

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The goal of this project is to determine the nucleation kinetics of solid phases within crystalline solids. More specifically, transmission electron microscopy (TEM) will be employed to obtain information on the rate of formation of precipitates controlled by atomic diffusion in the copper-rich Cu-Co system. Some of the TEM studies will be performed at the U. of Cal.—Berkeley high voltage electron microscopy facility in collaboration with Professor R. Gronsky. The data will be used to test critically three forms of nucleation theory (classical theory, Cahn-Hilliard continuum non-classical theory, and discrete lattice point (DLP) theory), and recent theoretical extensions to account for anisotropies in the interfacial free energies of this system. The studies will then be extended to Al-Ag alloys which undergo more complicated phase transformations. Zero creep and thermal grooving techniques will be used to determine coherent and partially coherent interphase boundary energies. This is a continuation of research previously supported under NSF Grant DMR79-17018 A01. This is the first year of a three-year continuing grant.

2. Fundamentals of Solidification at Rapid Rate

Current Award: 69.6/12/3CN
Effective Date: 6/1/82

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The goals of this study are to characterize the nonequilibrium interface conditions prevalent during rapid solidification of metallic materials, and their relative roles in determining the final microstructure. Much of the available information about solidification kinetics, interface instability, solute redistribution and microstructural evolution during rapid rate solidification cannot be explained using theories which assume the existence of local equilibrium at the solid-liquid interface. This project will provide essential data on interface kinetics as a function of interface cooling rates and composition, on the nonequilibrium distribution coefficient as a function of the solidification rate, composition and orientation, and on the interface morphology as affected by the thermal, compositional, and interfacial kinetic conditions. This information is necessary to develop and assess new theories to explain nonequilibrium evolved microstructures. The interface supercooling will be measured directly, and its shape and velocity will be directly observed for the Ga, Ga-Al, Ga-Ag and Ga-Si systems. This is the first year of a new three-year continuing grant.

3. Impact of Strain Inhomogeneity and Recovery Annealing on the Multiaxial Yield Behavior of Prestrained Single Phase Metals

Current Award: 49.1/12/3CN
Effective Date: 2/1/82

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The goal of this study is to determine the extent to which strain inhomogeneity contributes to the anisotropic yield behavior of single phase metallic systems. Previous research has shown that small-scale yield behavior is highly anisotropic and prone to complex Bauschinger effects when strained in directions reverse or orthogonal to those of prestraining. A second objective is to extend available theories of plasticity of yielding to include multiaxial yield behavior of single phase metallic materials subjected to various prestraining and recovery annealing histories. Thin-walled tubes of Al, Cu and Zr alloys will be subjected to internal pressurization and tensile or compressive longitudinal loads to various biaxial stress states. Strain measurements will provide information about the yield stress, and x-ray line broadening measurements will define the strain inhomogeneity as a function of crystallite orientation. Experiments will be done under various conditions of prestraining and recovery annealing. This is the first year of a new three-year continuing grant.

4. Transport Studies on Pitting Corrosion

Current Award: 90.0/12/3CR
Effective Date: 7/1/82

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The objectives of this study are to understand corrosion by pitting and etch tunnel formation, to develop quantitative models to predict corrosion behavior, and to transform scientific, mechanistic understanding into technological design principles to predict corrosion-resistant combinations of materials. The research includes experimental and theoretical work, with strong emphasis on the use of mathematical models to evaluate formulated hypotheses on corrosion mechanisms. The transport phenomena principles included in models developed under this program include mass transfer, ohmic resistance, interface charge transfer, homogeneous reactions, and geometric shape change. Metallic systems under investigation include Fe, Co, Ni, Cr, Mo, Ti, Al, Mg and stainless steels. The electrolytes include chloride-containing acidic systems, especially mineral acids such as sulfuric and phosphoric. A new experimental method is being developed, which uses focused laser illumination to initiate single corrosion pits on otherwise passive surfaces. Special emphasis is placed on clarifying conditions which result in repassivation of newly formed pits or promote the evolution of deeply penetrating pit configurations. In addition, new theoretical computations based on finite element numerical methods are employed to study transient corrosion behavior, including shape change during early stages of pit and etch tunnel formation, and the results are compared with experimental data. This is the first year of a three-year continuing grant, extending research previously supported under NSF Grant DMR77-28285 A02.

5. Unified Theoretical and Experimental Approach to the Study of Internal Surfaces in Solids

Current Award: 90.1/12/3CR
Effective Date: 2/1/82

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This is a theoretical and experimental study to determine the underlying principles which govern the structure, chemistry and ultimate properties of internal surfaces in metallic solids. The theories of non-uniform systems and statistical mechanics, as well as kinetic principles, are used to model important interface properties in metallic systems. The current program emphasis is directed toward understanding a simple class of interfaces: coherent antiphase and interphase boundaries and their migration in long-range ordered Fe-Al alloys. More specifically, the relative roles of interfacial free energy, adsorption, diffuseness of the interface region, and stability of the boundary shape in controlling interfacial migration kinetics is under study. The variation of the interfacial free energies with temperature and alloy composition, and the interfacial region structure will be determined. Theoretical studies underway include: (i) the stability of an adsorbed layer at a migrating interface in Fe-Al alloys; and (ii) extension of the two-dimensionally theoretically derived constraints to three-dimensional systems. Experimental studies of interfacial structural phase transitions in Cu-Au alloys (predicted by Kikuchi and Cahn) are underway, using conventional and high resolution microscopy techniques. This is a continuation of research previously supported under NSF Grant DMR76-20662 A01. This is the second year of a three-year continuing grant.

6. Hydrogen Embrittlement in the Iron-Nickel-Chromium System

Current Award: 176.4/12/5CR(C.E.)
Effective Date: 4/1/82

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The objective of this investigation is to determine the fundamental mechanisms responsible for hydrogen embrittlement in the Fe-Ni-Cr system. This is a model system for numerous important engineering alloy systems, and exhibits stress corrosion cracking and a variety of hydrogen effects which influence mechanical behavior. These include the cracking and loss of ductility of austenitic stainless steels, and degraded creep resistance in Ni-base alloys in the presence of hydrogen gas. Emphasis is placed on the mechanisms responsible for these effects and on understanding their interrelationships. In the past two years, emphasis has been placed on the use of improved Secondary Ion Mass Spectroscopy, Auger Spectroscopy, and Prompt Ion Induced Autoradiography techniques, with very high hydrogen sensitivities and high spatial resolution to detect and determine hydrogen localization. There is a strong focus on understanding basic mechanisms of environmentally related fracture, and extension of this knowledge to understand and predict the mechanical behavior of technologically important alloys. This is a continuation of research previously supported under NSF Grant DMR74-24648 A02. This is the fifth year of a five-year continuing grant. The last two years of this study have been supported under a two-year extension for Special Creativity.

7. Transient Alloys Dissolution Kinetics of Rotation Ring Disc Electrodes

Current Award: 24.9/6/S
Effective Date: 3/1/82

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This is a study to determine the transient dissolution kinetics for individual constituents of Fe-Cr-Mo alloys using a combination of conventional rotating ring disc voltammetry with a device for mechanical electrode depassivation. The effect of applied potential, solution pH, and mass transport on high purity iron dissolution kinetics is being studied as a function of chloride and molybdate ion solutions. Surface composition profiles and hydrolysis kinetics are being measured for Fe-Mo alloys. Fe-Cr-Mo alloys and a high purity Cr rotating ring disc electrode are used to detect possible interactions between the Cr dissolution products $MoO_4^=$ and Cl^-. This is a supplement to a new two-year research grant.

8. Dislocation Annihilation and High Temperature Mechanical Behavior

Current Award: 66.3/12/3CR
Effective Date: 7/15/82

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The goal of this project is to modify models of transient creep, and to assess the models by independent experimental determinations of the various parameters. More specifically, a modification to the theory of Ajaja and Ardell will be effected, which stipulates that dislocation multiplication can proceed only if the dislocation density, ρ, is less than some saturation value which is a function of the applied stress. For class II materials (i.e., creep behavior is characterized by a decrease in ρ with increasing strain,ϵ) the saturation value is the initial value of ρ which the sample acquires on loading. It has thus far been demonstrated qualitatively that the modified theory is consistent with the maximum in ρ observed during constant strain rate testing. Elevated temperature mechanical behavior experiments are underway on monocrystalline NaCl and single crystals of Al or Cu (oriented for multiple slip), and on textured Fe-3% Si to determine whether the behavior thus far observed for NaCl (exhibiting a decrease in ρ with increasing ϵ in creep studies) is typical of class II materials, and to provide a critical test of the modified theory. This is a continuation of research previously supported under NSF Grant DMR78-26059. This is the second year of a three-year continuing grant.

9. Dislocation Distribution in Creep and Relaxation

Current Award: 80.0/15/3CN
Effective Date: 8/15/81

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It is known that the dislocation density in the near surface region is high compared to the interior of plastically deformed metallic materials. Furthermore, the dislocation density in the interior of fatigued polycrystalline Al alloys is reduced to that of virgin specimens when the surface layer is removed, and a fatigue mode of failure occurs when the dislocation density in the surface and the bulk are approximately equal. This implies that the dislocation density in the interior would not have increased if the surface layer had not formed during the fatigue process, and that the rate of dislocation "build-up" within the interior of a metallic material is controlled by the dislocation "build-up" in the surface layer. Very similar effects have been observed for creep, stress-corrosion cracking, fatigue-creep, and corrosion-fatigue environmental conditions. The goal of this investigation is to determine the role of the surface in controlling the mechanical behavior of metallic materials deformed by high temperature creep, and the possible change in surface conditions/effects during relaxation. Experimentally, the dislocation-density-depth profile that forms during creep and relaxation processes will be determined as a function of strain, stress, temperature and prior thermomechanical processing history on high purity polycrystalline Al and Cu metals and binary alloys. The relaxation process will also be investigated as a function of environment (stress corrosion cracking media), and creep-fatigue interaction experiments will be undertaken. A computer simulation model will be developed which takes into account: (i) higher dislocation densities in the near surface region in samples deformed by high temperature creep; and (ii) dislocation motion in a periodic internal stress field with a random array of short range barriers. It is expected the results of this research will define the role of surface layers in controlling the fatigue, creep, creep-fatigue, stress corrosion and corrosion-fatigue characteristics of metallic materials. This is the first year of a new three-year continuing grant.

10. Fundamental Studies of Localized Plastic Deformation

Current Award: 38.9/12/3CN
Effective Date: 4/1/82

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The goals of this investigation are: (i) to determine conditions which cause plastic deformation to become localized in ductile single crystals of pure, single phase metallic materials; (ii) to develop and solve appropriate constitutive relations to describe the initiation and evolution of non-uniform deformation of single crystals; (iii) to formulate "self-consistent" models for plastically deformed polycrystals; and (iv) to determine the extent to which localized deformation in single crystals causes material damage and contributes to fracture. X-ray diffraction and topographic methods are employed to obtain information on the kinematics of localized shearing. The single crystals of Al and Cu, and age-hardened alloys of Al-Zn and Cu-Co at temperatures between 77° and 298°K. This is the third year of a new three-year continuing grant.

11. Systematic Investigation of Grain Boundary Structure in Thin Films by Transmission Electron Microscopy

Current Award: 80.0/16/40CR
Effective Date: 7/1/81

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This is a study of grain boundary structures and concomitant thermodynamic and kinetic properties using lattice-fringe imaging and high resolution transmission electron microscopy (TEM) techniques with advanced analytical capabilities. Bicrystalline thin films of various materials (Al, Ni, Cu, Au, Ag, Pd, Cr, Nb, Si, CdS, GaAs, and alloys thereof) are made by a vapor deposition process on preselected bicrystalline substrates of NaCl and subsequent epitaxial growth. These films are characterized by close dimensional tolerances, contain grain boundaries of desired misorientation, and are amenable to direct observation by TEM without further preparation. The films are then used to investigate grain boundary structure in pure materials, grain boundary (triple) junctions, grain boundary structure and properties in binary alloys, and kinetic properties of grain boundaries. It is expected the results of this program will advance understanding of structure and concomitant properties of grain and interphase boundaries, such as interfacial diffusion, mobility, and resistance to electromigration. This is a continuation of research previously supported by NSF Grant DMR76-11373 A02. This is the first funding period of a forty-month continuing grant.

12. Strengthening Mechanisms of Warm-Rolled Ferrous Materials

Current Award: 46.0/12/3CN
Effective Date: 3/15/82

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The goal of this study is to determine the relative effects of several microstructural features on the room temperature yield strength of unalloyed Fe and Si-Fe. The microstructural features to which the strength increase is attributed are grain boundaries, subgrain boundaries and bulk dislocations. The relative contributions of these features will be varied by warm rolling the metals at intermediate temperatures (450° to 750°). A predictive equation will be developed to estimate the yield strength of warm-rolled ferritic materials and which can be used to design a thermomechanical processing schedule for a dual-phase steel. The results of this research are expected to improve understanding of the mechanical behavior of ferrous materials deformed at intermediate temperatures, extend present understanding of the interrelationship of grains, subgrains and dislocations as strengthening mechanisms, and provide a systematic evaluation of warm rolling as a useful deformation process. This is the first year of a new, three-year continuing grant.

13. Yield of Anisotropic Materials Under Combined Stress

Current Award: 37.0/12/2CN
Effective Date: 7/1/81

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The goal of this program is to determine experimentally how the plastic anisotropy of face-centered-cubic and body-centered-cubic sheet metals is best characterized by the strain ratios measured in uniaxial tension tests. Hill's anisotropic plasticity theory has been widely used to predict the yielding behavior under complex loading from tension test results. However, recent calculations of yield loci shapes from considerations of slip and experimental evidence indicate large deviations from the Hill theory. Rather than determining complex yield loci, bulge tests, plane-strain tension tests and uniaxial tension tests are being performed on a number of strongly textured sheet materials. These loading paths permit critical comparison with various anisotropic yield criteria. A secondary objective is to assess the bulge test which is widely used to determine biaxial yield strength, since there are several reservations about how bulge test data are obtained and analyzed. The first relates to assumptions involved in measurement of the radius of curvature, while the second concern is how to analyze deviations from biaxiality. Finally, there is the question of determining the effective strains in bulge testing so that the results are comparable with uniaxial test data. This is the second year of a new two-year continuing grant.

14. Studies on the Passivation of Iron and Ferrous Alloys Using In-Situ Optical and Electron Spectrographic Techniques

Current Award: 50.0/12/3CN
Effective Date: 7/1/81

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The goal of this study is to characterize the structure of passive films on Fe, Ni, Cr and their alloys and to determine the mechanism(s) of their formation and breakdown. Several non-electrochemical techniques are employed along with modern electrochemical methods for this investigation: (i) automatic ellipsometric spectroscopy (to follow the dynamics of growth and reduction, and optical properties of the passive film on pure Fe as functions of time, potential and wavelength); (ii) AC electromodulation reflectance spectroscopy and electrical impedance of the passive film over a wide (10 Hz to 10 KHz) frequency range; and (iii) ESCA studies of the composition of passive films produced on Fe, Ni, Cr and alloys of these materials as a function of potential. Results of these experiments are being correlated with other projects, including studies on the optical characteristics of thin films and in-situ high voltage (450 kv) electron microscopy studies of thin film iron oxides in an atmosphere containing O_2 and H_2O vapor. This is the third year of a new three-year continuing grant.

15. Acoustic Emission Generated During the Deformation of Crystalline Materials

Current Award: 77.3/12/3CR
Effective Date: 7/1/82

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The goals of this investigation are to correlate specific features/characteristics of acoustic emission patterns generated during the deformation of crystalline solids with specific deformation mechanisms, to determine how metallurgical variances affect both the deformation and acoustic emissions, and to advance acoustic emission methodology to its full potential as a very powerful diagnostic tool for analyses of deformation processes/mechanisms of materials. Although many acoustic emission parameters will be measured, particular emphasis is given to wave form analysis (not mean squared voltage and amplitude distributions). Specific studies to be done include grain size, purity and strain rate dependence of acoustic emissions for Fe, Al and Zn. Research underway and to continue includes investigations of mechanisms of dislocation avalanche motion observed at the yield point, to determine if the controlling mechanism is stress dependent, strain dependent or plastic strain dependent. Lastly, the acoustic emission generated during the fracture and/or debonding of second phase particles will be investigated, with the expectation of characterizing the effects of density, size and particle morphology. This is a continuation of research previously supported by NSF Grant DMR77-23782 A02. This is the second year of a three-year continuing grant.

16. Phase Investigation of Lead-Tin-Calcium Alloys

Current Award: 83.4/12/3CN
(41.7 from Metallurgy, 41.7 from IUC)
Effective Date: 7/15/82

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This is a fundamental industry/university cooperative research program to determine phase relationships of ternary Pb-Sn-Ca alloys and precipitation kinetics of Sn-rich and Pb-rich binary and ternary systems, of importance for use in batteries. To date, phase equilibria characteristics of the Pb-Ca and Sn-Ca binary systems have been determined experimentally using differential thermal analysis, x-ray, microprobe analysis and metallographic methods. Using thermodynamic estimates of the ternary system Pb-Sn-Ca, specific ternary alloys of importance to batteries were prepared, and advanced experiments are underway to identify the compounds and series of solid solutions formed in the delta phase. The results of theoretical computations on the free energy differences between the face-centered tetragonal structures of Pb and Sn, as well as details of phases present, were found to be in good agreement with experimental data. Advanced experiments are underway to obtain kinetic and aging information on Pb-Sn-Ca alloys, as well as theoretical modelling and phase diagram computations for the Pb-Ca, Sn-Ca, Pb-Te and Pb-Sn-Ca systems. This is the third-year of a new three-year continuing grant.

17. Thermodynamic and Phase Relationships of Binary and Ternary Metal-Sulfur Systems

Current Award: 89.4/12/5CR(C.E.)
Effective Date: 9/1/82

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The goal of this study is to extend experimental and theoretical thermodynamic and phase equilibria knowledge on ternary $metal_1$-$metal_2$ sulfur systems in the solid state, and to determine the effect of oxygen on the characteristics/properties of these systems. The metallic elements under study are Fe, Co, Ni and Cr. A statistical thermodynamic model is being developed to describe the properties of the ternary monosulfide phase with the NiAs structure and to describe the thermodynamic behavior of the metal-sulfur melts as a function of composition and temperature. This is a continuation of research previously supported under NSF Grant DMR76-16999 A02. This is the fifth year of a five-year continuing grant. The last two years of this study have been supported under a two-year extension for Special Creativity.

18. A Study of Surface Layer Damage Due to Indentation Fatigue

Current Award: 55.8/12/3CR
Effective Date: 8/1/82

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The goal of this program is to determine the mechanism(s) of material damage due to repeated particle impingement (i.e., the relationship between surface hardening, the development of surface layer damage due to indentation fatigue, and the eventual removal of material from the surface). Single and multiple impact indentation fatigue testers are used to study possible interactions between neighboring impacts, and their relative contribution to the erosion process. Target materials include Cu and Fe-Si in single crystal and polycrystalline forms. Regions on or below an impacted surface are characterized using thin film microscopy techniques. Static elastic-plastic analyses of repeated impacts are underway, and comparisons are made between theoretical predictions and experimental data with respect to plastic flow behavior, subsurface layer damage and crack initiation. Advanced phases of experimental and analytical work are underway, including: (i) the effect of contact surface friction condition on plastic flow and crack initiation; (ii) interactions among neighboring indenters; and (iii) oblique indentations. This is a continuation of research previously supported under NSF Grant DMR81-40257 A01. This is the third year of a three-year continuing grant.

19. Grain Boundary Pinning of Flux Lines in Niobium Bicrystals

Current Award: 64.0/12/3CN
Effective Date: 9/1/81

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The goal of this investigation is to understand grain boundary flux pinning effects/phenomena in Nb bicrystals. Oriented bicrystals are grown from the melt, and segregation of impurities to the grain boundary are determined by Auger analysis. Critical current measurements as a function of applied magnetic field and angle between the field and the grain boundary, are done at Oak Ridge National Laboratory in collaboration with Dr. Das Gupta. In addition, experiments are underway: (i) to determine the effect of introducing controlled amounts of oxygen on the corrosion rate and solute segregation behavior on low and high angle tilt boundary bicrystals; (ii) to determine the grain boundary diffusivity of Ta in Nb bicrystals; and (iii) to characterize the effect of Ta on the critical current in Nb bicrystals. Lastly, theoretical studies will be done to determine the pinning force between a pin and the flux line lattice, and details of interaction between the flux line lattice and an edge dislocation wall containing a microledge will be examined. This is the third year of a new three-year continuing grant.

20. Microstructural Evolution During Ion Implantation

Current Award: 273.0/12/3CR
Effective Date: 6/1/82

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Phone: (412)624-4347

This is a fundamental investigation into the nature of atomic events and microstructural processes underway during and as a consequence of ion bombardment of metallic and nonmetallic materials, and of coupling phenomena/mechanisms between atomic displacement and compositional (dopant) effects. Questions being addressed include: (i) do ions of different mass and energy produce fundamentally different damage states (ii) does the incessant atomic displacement which produces many point defects affect the mobility of the implanted ions (iii) what is the applicability of rate theory models to implantation metallurgy effects and (iv) can the ion beam techniques of ion channeling and backscattering which have been so successfully applied to semiconductors to identify lattice sites occupied by dopant atoms and to measure dopant concentration and damage profiles, be applied equally advantageously to this research problem? Areas of emphasis include: (i) the coupling of atomic displacement events with dopant atom events (He, B, C, N, O, Si in Mo, Al and Cu single crystal systems); (ii) the role of stress effects in ion implantation (implanted polycrystalline 304 stainless steel, Mo, Al and single crystals of Mo and Al); and (iii) the compositional effects near the sample surfaces due to surface impurities, recoil processes, and thermal redistribution of host atoms (Fe-Cr-Ni ternary systems, Mo, Al and Cu). This is a collaborative research program between materials scientists at the University of Pittsburgh and the Westinghouse Research and Development Center. This is a continuation of research previously supported by NSF Grant DMR78-02598 A02. This is the second year of a three-year continuing grant.

21. The Role of Surface Conditions on Fatigue Crack Initiation in Iron and Steels

Current Award: 94.9/12/3CN
(51.0/12 from Metallurgy Program and 43.9/12 from IUC)
Effective Date: 7/1/82

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[2]Inland Steel Research Laboratories

This is an industry/university cooperative research study to determine the role of various surface conditions (including environment (oxygen, water vapor, and ultra-high vacuum), specific types of surface oxides, decarburization, diffused overlayers, surface irregularities, and near-surface coarsening) on surface deformation and fatigue crack initiation in commercially pure iron, binary Fe-C and Nb-microalloyed steels. Ex-situ fatigue crack initiation studies are done on Auger and ESCA characterized surfaces as a function of the surface oxide composition and thickness. In addition, in-situ fatigue properties of the above materials whose surfaces are prepared within an ultrahigh vacuum scanning Auger microprobe with varying surface topology and composition are being measured, and the results are being correlated with those of the ex-situ experiments. Theoretical studies are underway to determine the influence of the oxide coatings on fatigue crack initiation. This is the third year of a new three-year continuing grant.

22. Statistical Mechanical Model of Nucleation and Growth in Martensitic Transformations

Current Award: 80.6/12/3CR
Effective Date: 7/1/82

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This is a theoretical study aimed at developing a general theory of the precursor, nucleation and growth stages of first order martensitic transformations, using molecular dynamics as the principal calculational method. Based on the successful simulation of martensitic nucleation and growth for body-centered-cubic to orthorhombic, as well as a body-centered-cubic to face-centered-cubic transformation using modified potentials, it is now possible to determine and understand important characteristics of the transformation process in real systems. Research to be performed during the next three years will focus on: (i) determining the role of localized soft modes in first order martensitic transformations; (ii) simulating the martensitic transformations in Na using a very accurate pseudopotential, and comparing predicted crystallographic relationships, neutron scattering behavior, and transformation temperature with experimental data; (iii) construction of a semi-empirical potential for Fe-30Ni, simulation of the martensitic transformation in this alloy, and comparison of similar predictions with experiments but including acoustic attenuation data; (iv) analysis of the effect of different lattice defects on the nucleation process for selected transformations; and (v) development of an analytic theory of martensitic nucleation. This is a continuation of research previously supported by NSF Grant DMR80-07031 A01. This is the first year of a three-year continuing grant.

23. Passivity and Breakdown of Passivity of Stainless Steels

Current Award: 61.9/12/32CN
Effective Date: 7/1/82

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The relationship between the nature, characteristics and corrosive properties of passive films formed on Fe-Cr stainless steels which contain Ni and/or Mo as compared with those which do not contain these elements is not understood. In this investigation, controlled amounts of Ni and Mo are systematically added to Fe-Cr alloys, singularly and together, with the objectives of: (i) understanding the effects of these additions from analysis of structural, compositional and thickness data; and (ii) determining the mechanisms of passivity and its breakdown for Fe-Cr stainless steels. The determined mechanisms will be compared with those observed for commercial grade 304, 316 and 430 stainless steels. The experiments are done on films formed under controlled potential conditions in sulphate solutions in the pH range from less than unity to seven. Modern surface techniques are used to obtain structural and compositional data on the passive film and the alloy at the metal-oxide interface. The products of anodic dissolution are analyzed to assist in determining operational processes during the formation and aging of passive films and during exposure to Cl^- ions. This is the second year of a new thirty-two month continuing grant.

24. Local Atomic Arrangements in Alloys and Intermetallics

Current Award: 72.0/12/5CR(C.E.)
Effective Date: 3/1/82

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This project employs x-ray and neutron diffraction techniques to determine local atomic arrangements in alloys and intermetallics and to test theories of phase transformation. Special emphasis is placed on spinodal theory, precursor effects in first order transitions, determination of force constants in the modern theory of continuous transformation, and extension of diffuse scattering analyses to higher-order systems. Feasibility diffuse scattering experiments from Guinier-Preston (G.P.) zones are underway using the Cornell high energy synchrotron source, to determine the genesis/evolution of G.P. zones in Al-Cu binary alloys. Recently, experiments were initiated to understand the observed narrowing of the miscibility gap in Al-Ag alloys above 170°C and the nature of the G.P. zones formed. Phonon dispersion curve data obtained on Au-Ni single crystals at 750°C are being analyzed together with x-ray diffuse scattering data to determine the force constants for this sytem. This information is needed to critically test the Cook-de Fontaine theory of continuous transformations. This is a continuation of research previously supported under NSF Grant DMR79-23825 A02. This project is in the third year of a three-year continuing grant, and has recently been approved for an additional two-year extension for Special Creativity.

25. Nucleation and Growth of Solid State Transformations

Current Award: 137.6/12/5CR(C.E.)
Effective Date: 12/1/81

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The mechanisms of nucleation and growth in martensitic transformations are being investigated theoretically and experimentally toward the ultimate objective of understanding and controlling the overall reaction kinetics as well as the morphology of the transformation product. There has been a shift of emphasis in this work from the nucleation phenomena to the structure of the generated interphase boundaries, and to the propagation dynamics of such interfaces. The interface-velocity law involves a generalized thermodynamic driving force for the nonisothermal, nonadiabatic conditions at play, the dislocation structure of the interphase boundary as determined by the crystallography of the lattice and lattice-invariant deformations, and the degree of elastic versus plastic accomodation of the operative transformational shape change. The closely-coupled interactions among these processes are considered to govern the fine structure of the transformation product and, hence, to play a guiding role in the manipulation of certain structure-property relationships. Theoretical work is underway, using the concepts of martensitic crystallographic theory to develop a general theory of interfacial structure. This is a continuation of research previously supported under NSF Grant DMR76-22993 A02. This project is in the third year of a three-year continuing grant, and has recently been approved for an additional two-year extension for Special Creativity.

26. Lattice Defects in Metals Studied by Hyperfine Interactions

Current Award: 47.7/12/3CN
Effective Date: 7/15/82

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This research is directed toward gaining a better understanding of macroscopic materials properties in terms of atomic scale phenomena and includes: (i) studies of transformation rules that lead from single vacancies to clusters of vacancies nucleating around isolated heavy impurities in irradiated and quenched samples of face-centered-cubic metals; (ii) studies of vacancy-impurity cluster formation and growth as a result of plastic deformation, and correlation of these results with stages of work-hardening; (iii) search for high temperature binding in heavy-atom-vacancy clusters; and (iv) study of possible probe dependence in impurity-vacancy binding. The primary experimental technique(s) to be used are Mossbauer Spectroscopy and the method of perturbed angular correlations. This is the second year of a new three-year continuing grant.

27. Interphase Boundary Initiated Fracture

Current Award: 132.3/12/3CN
Effective Date: 7/15/82

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The goal of this investigation is to determine the fracture initiation and propagation processes of a model two phase metallic material, Co-Co Al, as effected by the chemistry and structure of the interphase boundary. Experimental studies involve extension of previously successful efforts to predict fracture toughness of equiaxed elastic-plastic alloys for this system, from temperatures where no plastic recovery effects occur to temperatures where significant recovery effects are operative. Plastic strains observed in previous studies were sufficiently large so as to smooth out the inherent inhomogeneities of plastic deformation. In lamellar eutectic alloys of this system, this heterogeneity significantly affects the fracture event. This effect is being studied using finite element and analytical approaches in an effort to define underlying failure criteria of delamination, elastic phase fracture, or (if constraints are sufficiently great) elastic phase yielding, in terms of observable experimental parameters (i.e., applied tensile/compressive stress, overall strain, etc.). Concurrently, experimental studies over a broad range of temperature and strain rates are underway, varying from creep behavior to conditions of dynamic shock loading. These microchemical approaches are augmented further by computer simulation studies of atomic behavior in the vicinity of cracks and other heterogeneities at the interface between two phases. The ultimate objective is to merge the two approaches so as to relate microscopic mechanical analyses to behavior at the atomic level. This is an extension of research, previously supported under NSF Grant DMR78-05741 A02. This is the first year of a three-year continuing grant.

28. Modelling of Deformation Inhomogeneities in Upset Forging

Current Award: 49.6/12/3CN
Effective Date: 12/15/81

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This is a combined experimental and theoretical program to study the elastic and plastic response of metals during upset forging. This is a complex problem involving a large number of variables including the friction between the work piece and the forging die, the inhomogeneous temperature profiles induced during forging, microscopic changes within the material and finally the complex stress state within the material. Such a problem is extremely difficult to solve exactly. It is currently feasible to solve this problem exactly only using restrictive geometries. The principal investigators have developed a simplified empirical model which utilized some experimentally determined parameters. With this model they are able to predict such parameters as the location of the elastic/plastic interface within the material and the bulge profile, parameters of technological importance. In the present research the investigators are extending the model with the use of additional experiments. This is the second year of a new three-year continuing grant.

29. Clustering and Ordering Instabilities in Multicomponent Systems

Current Award: 102.9/12/5CR(C.E.)
Effective Date: 7/1/82

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This is a theoretical and experimental investigation of various phenomena (clustering, ordering, coarsening, coherent precipitation, kinetics of spinodal decomposition, phase equilibria, and topology of ternary eutectics) in select model systems (Cu-Ag-Au, Al-Zn-Mg and Al-Zn-Ag). Statistical thermodynamic formalisms are used to predict important details/characteristics of these phenomena, and numerous experimental methods are used to test the theory, such as small angle x-ray scattering, synchrotron radiation and high resolution electron microscopy. This is a continuation of research previously supported under NSF Grant DMR77-23578 A02. This is the fifth year of a five-year continuing grant, the last two years of which have been supported under a two-year extension for Special Creativity.

30. Kinetics of Slag-Metal Reactions in Welding

Current Award: 70.0/12/3CR
Effective Date: 6/15/82

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This is a thermodynamic and kinetic study of reactions which occur during flux shielded welding of carbon steel, alloy steels and stainless steels. Although the primary process under investigation is submerged arc welding, gas metal arc and shielded metal arc welding will also be studied. The reactions are separated into three primary zones: the plasma-droplet; the plasma-weld pool; and the slag-metal pool. The latter zone is of particular importance in determining the detachability of welding slags. Two major flux systems will be used in these studies, manganese silicate and calcium silicate. High current pulsing techniques are used to control independently the size of the droplets and the time of flight through the plasma. High-speed spectroscopy of the flux-cored welds is used to determine the species present in the plasma. Techniques to be used to determine the chemical, physical and geometric factors controlling slag detachability include V-groove testing and instrumented shear testing of patches (to quantify detachability) and the usual methods (x-ray microprobe, scanning electron microscopy and/or Auger analysis of surface segregates, microprobe and x-ray analyses of surface slag phases and for compositional gradient analyses in the slag and metal phases) to determine the interface composition as a function of welding parameters. This is a continuation of research, previously supported by NSF grant DMR79-26324 A01. This is the first year of a three-year continuing grant.

31. Local Atomic Structure of Amorphous Alloys

Current Award: 86.3/12/34CN
Effective Date: 6/1/82

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Recent experimental and theoretical studies of amorphous alloys indicate the importance of the local structural fluctuations in elucidating various physical properties. In particular, recent work suggests the usefulness of the concept of structural defects in amorphous solids, defined in terms of local parameters such as the atomic level stresses. Since the size of such defects is only a few atomic distances, direct observation of defects will be investigated using the energy dispersive x-ray diffraction method. The approach includes medium to low angle ($0.1 < q < 2A^{-1}$) diffraction. Calculations show that the structure factor in this range contains important information. In addition, the first peak of the radial distribution function will be analyzed as well as the effect of plastic deformation and radiation on the local structure. Most of the research will be carried out using conventional x-ray sources, but synchrotron radiation may be employed at a later stage. The model calculation will be developed further to interpret the experimental results. Materials to be investigated include, Fe-B, Fe-B-C, Fe-B-Si, (Fe-Ni) P-B, and Fe-Zr variable composition amorphous alloys. This is the second year of a new thirty-four month continuing grant.

32. Atomic Exploration of Crystal Growth and Reactivity on Metals

Current Award: 122.6/12/3CR
(35.0 from Metallurgy, and 87.6 from Solid State Chemistry)
Effective Date: 5/15/82

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The goals of this research are to enhance understanding of: (i) the kinetics and energetics of crystal growth processes of metals on an atomic scale; and (ii) the mobility of gases on metallic surfaces and reactions between gases and metals. The primary experimental techniques employed are field ion microscopy, field emission microscopy, and Auger spectroscopy. Research on atomic exploration of crystal growth processes will concentrate on interactions of Re atoms on various crystallographic planes of W. The studies will emphasize: (i) atomic events in nucleation: conditions of cluster formation and structural transformations in clusters; behavior of vacancies, adatoms, and clusters during diffusion on metals; and (ii) interactions between adatoms and lattice steps: energetics of two- and three-body interactions between metal adatoms, and between adatoms and lattice steps. Research on surface diffusion and reactivity of gases will involve the diffusion of O and N on W, and N on Mo. The gas reaction studies will involve the interaction of nitrogen with certain crystallographic planes of iridium. Emphasis will be on: (1) surface structure and the mobility of gases on metals; and (2) reactivity of surface clusters: clusters will be produced by vapor deposition on a metal and characterized by field ion microscopy. The rate of dissociative chemisorption will then be examined by field emission microscopy. This is a continuation of research previously supported under NSF grants DMR78-25015 and DMR80-24061. This is the first year of a three-year continuing grant.

33. Solid Solution Strengthening and Weakening

Current Award: 79.2/12/3CR
Effective Date: 8/1/82

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Quantitative theories are being developed for substitutional solid solution effects on the mechanical properties of body-centered-cubic and face-centered-cubic alloys. Emphasis is on avoidance of arbitrary empirical assumptions, and both atomistic and semicontinuum models for solute atom-dislocation interactions are employed. In particular, it is anticipated that many of the "core" effects obtained from the atomistic studies can be applied to remove some of the ambiguities and questionable assumptions inherent in the semicontinuum models. Particularly novel is the application of the electronic tight-binding model to calculate interatomic forces. The forces are intrinsically non-central in nature. Use will be made of several recent advances in the tight-binding field, including efficient new force calculation techniques developed by one of the investigators on this grant. Some experimental work (elastic constant measurements, phonon spectra) will be undertaken to provide data for critical assessment of the theoretical models. The ultimate goal of this research is to develop a unified atomistic/continuum model of substitutional solid solution strengthening and weakening in concentrated alloys. This is a continuation of research, previously supported under NSF Grant DMR79-00902 A02. This is the first year of a three-year continuing grant.

34. The Physical and Electrochemical Basis of Fatigue Damage

Current Award: 144.5/12/3CR
Effective Date: 1/15/82

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This is a fundamental investigation of fatigue damage of single and polycrystalline metallic materials under conditions of variable loading, and in various aqueous and gaseous environments. Although copper is the primary material under study, the results obtained are expected to be applicable to a wide range of metals and alloys, including body-centered-cubic materials under certain conditions. The studies underway include: (1) the behavior of persistent slip bands (PSB) as a function of cumulative strain in two-step and multi-step tests, and documentation of the cyclic response during variable loadings; (2) the nature of cyclic deformation for strains in the plateau region if pre-testing is done at still higher strains (to determine the influence of dislocation cell structures on PSB behavior); (3) fatigue life behavior for plateau strains in multi-step tests; (4) development of models to predict cumulative damage, using the multi-step data; (5) the behavior of PSB's and fatigue life behavior under stress control rather than strain control; (6) the relationship between fracture and cyclic deformation mechanisms of monocrystals and polycrystals; (7) the role of the morphology of PSB's during mechanical testing in vacuum and the effect of gaseous species (water, oxygen and hydrogen) on the environmental/mechanical interaction at the surface of fatigued specimens; and (8) the role of aqueous environment and chemical reactions occurring under controlled potential polarization on PSB formation, crack nucleation mechanisms, and Stage I crack propagation.

This is a continuation of research previously funded under NSF grant DMR77-13934 A02. This is the second year of a three-year continuing grant.

35. Environment-Assisted Failure of Face-Centered-Cubic Iron-Base and Nickel-Base Alloys

Current Award: 61.9/6/S
Effective Date: 7/15/82

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This research program consists of six sub-projects directed toward understanding of environment-assisted failure (EAF) mechanisms in face-centered-cubic Fe-base and Ni-base alloys. It is a continuation of interdisciplinary studies of critical failure steps, ranging from those occurring on the passivated alloy surface to those occurring in the bulk alloy. Included are studies of new stainless steels (which may give maximum EAF resistance at minimum alloy cost), Ni_2Cr single and bi-crystals (which allow assessment of the relative roles of solute ordering and impurity segregation on embrittlement) and special Mo-bearing alloys (which allow definition of the mechanism of localized failure in these materials). Also included are ion-beam studies of local H concentration at grain boundaries and crack tips and studies of the effect of H on metal-metal bond strengths in model chemical systems. This is a joint Industry/University Cooperative research program involving materials scientists from Notre Dame University, Saint Mary's College and the Cabot Corporation. This is a continuation of research previously funded under NSF Grant DMR78-07167 A02. This is a supplement to a continuing grant.

36. Ductility Control in Body-Centered-Cubic Refractory Metals

Current Award: 59.2/12/3CR
Effective Date: 6/1/82

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The purpose of this research is to develop experimental methods for and a mechanistic understanding of ductility enhancement in body-centered-cubic metals at temperatures below 0.2 of the absolute melting temperature. The approach involves application of fundamental knowledge concerning dislocation dynamics, dislocation generation and multiplication processes, and dislocation-grain boundary interaction phenomena in body-centered-cubic metals. The major project involves determination of the strength of grain boundaries and the role of glissile dislocation-grain boundary interactions in the deformation of bcc metals. This work will be accomplished by experiments on mechanical testing of oriented bicrystals of tungsten combined with observations of dislocation substructures and grain boundary structures by transmission electron microscopy, optical microscopy and etch pit investigations. The project will make use of surface film softening effects discovered in Group VIb metals under previous NSF support to investigate specific dislocation-grain boundary interactions. A second study will be concerned with the investigation of effects of point defect and volume obstacles to dislocation motion on the surface film softening phenomenon observed in tungsten. The obstacles to be examined will include interstitial and substitutional solutes and small ($\sim$20 nm) potassium bubbles that are typically present in commercial tungsten filament material. Selected experiments on molybdenum and Group VB metals niobium and tantalum will be performed to test the generality of the results obtained on tungsten. This is a continuation of research, previously supported under NSF Grant DMR78-05713 A02, and is the first year of a three-year continuing grant.

37. Solute Redistribution During Solidification

Current Award: 90.7/12/5CN(C.E.)
Effective Date: 7/1/82

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This is a fundamental investigation of solute/interface interactions during solidification. A model system, succinonitrile, for which the thermodynamic and transport properties are especially well known, is studied to ascertain how solute additions influence the kinetics of dendritic growth. Solutes are selected on the basis of their segregation coefficients, and are studied over the appropriate concentration ranges for which the growth kinetics and dendritic morphology of binary succinonitrile alloys can be studied as a function of supercooling. Specifically, kinetic studies are underway to determine the solute concentration and supercooling ranges over which the kinetic control shifts from thermal to solute diffusion. Also, the influence of solute additions on dendritic branch structure is being investigated, to elucidate how solutes alter the order of side-branching and affect the instability process. Diffusion coefficients are measured by techniques such as temperature gradient zone melting using droplet migration in thermal gradients controlled by ohmic heating. Ancillary measurements of transport properties (thermal and solute diffusivities, viscosity) and thermodynamic properties (solidus and liquidus temperatures, surface energy) are carried out when needed to check theory. The main research thrusts, however, are kinetic and morphological in nature, to obtain the most direct information on solute redistribution effects during solidification.

Where appropriate, scaling laws are tested on other systems to determine the generality of the kinetic description when two diffusants (heat and solute) are present. A new theoretical basis (termed multiparticle diffusion problem) was recently formulated to predict the evolution of rapidly solidified microstructures subsequent to their formation. Advanced phases of this theory are under development, since it has application to other important metallurgical processes involving coarsening phenomena, such as void growth during irradiation, liquid phase sintering, and precipitate growth from solid solution. Theoretical predictions of particle distribution functions at different volume fractions of solidified materials, particle size versus growth time, corresponding rate constants, and temperature distributions within two-phase systems are compared with precision thermometric data obtained on the model system P_4 and its alloys. This is the fifth year of a new continuing grant, the last two years of which were supported as a two-year extension to the three-year continuing grant for Special Creativity.

38. Interface Motion and Stress State During Early Stage Diffusion in Binary and Ternary Systems

Current Award: 89.7/18/42CN
Effective Date: 5/15/81

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This is a fundamental study of diffusional processes and related pressure effects including interface motion and intermediate phase formation, that occur during early stage diffusion in both binary and ternary systems. A number of binary systems and the Al-Ni-Cr ternary system have been selected as the model materials for study because of their importance to a number of both fundamental and commercial problems related to solid state joining (i.e., Al-Ni and Al-stainless steel) and to castings for superalloys. There are three areas of investigation. Analytical techniques with high spatial resolution for the quantitative measurement of the early stages of diffusion and intermediate phase formation will be developed using a scanning transmission electron microscope (STEM) equipped with an X-ray detector system. Then the microstructural and chemical phenomena which occur during the early stages of diffusion in a variety of binary (Cu-Zn, Cu-U, Al-Ag, Al-Ni) and ternary (NiCrAl) diffusion couples will be studied. This work will include the effect of controlled applied stress as an external driving force. Lastly, a quantitative model will be developed for the diffusion problem in a system with three elements, involving either the motion of a single two-phase interface or the development and growth of an intermediate phase. The combined studies will develop an understanding of how diffusional processes and the presence of a stress field influence bond formation and stability during solid state joining (diffusional bonding) or deposited coating processes. This award will support the first eighteen months of a new forty-two month continuing grant.

39. High Resolution Microscopy of Surface Interactions

Current Award: 65.0/12/3CR
Effective Date: 8/15/82

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This is a fundamental study on the structure of metallic surfaces and on the nature of atomic interactions through the study of surface diffusion. Research underway includes: (i) characterization of bonding on single crystal surfaces of Ni, Al and Fe through studies of the kinetics of metal adatom surface diffusion and single atom adsorption site geometry; and (ii) studies of the surface structure of single crystal elements expected to exhibit surface reconstruction (i.e., select surfaces of W, Mo, Ta, Nb, V, Si and Ge). Field ion microscopy and low energy electron diffraction are the primary experimental techniques employed in this study. It is expected the results of this research will significantly enhance understanding of surface and grain boundary phenomena and crystal growth processes, and the role of the surface in controlling the physical and chemical properties of metallic materials. This is a continuation of research previously supported under NSF Grant DMR78-07542 A01. This is the third year of a three-year continuing grant.

40. Analysis of Rolling Contact Fracture and Rim Life

Current Award: 89.1/12/3CN
Effective Date: 2/1/81

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This is a program to develop analyses of rolling contact fracture and an understanding of the metallurgical contributions to rim life. The research will develop two-dimensional elastic-plastic finite element models of contact (without heating) and of heating (without contact). Residual stress distributions and cumulative strain distributions in the rim will be determined for a range of loadings and contacts on a number of well-characterized materials. These determinations will be used to validate (and adjust, as necessary) existing analyses and to test finite element computations. Finally, the research will be used to define the rates of crack initiation and cyclic crack growth and to extend analysis to rim life. This is the first year of a new three-year continuing grant.

41. Deformation Processing by Hydrostatic Coextrusion

Current Award: 83.9/12/3CN
Effective Date: 6/15/82

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The objective of this investigation is to characterize the deformation by hydro-static coextrusion of a two-component billet in which the mechanical and metallurgical characteristics of the components are dissimilar. The principal independent variables are: (a) relative amounts of each constituent; (b) disposition (hard core/soft clad and hard clad/soft core); and (c) amount of deformation. The effect of process variables on the microstructure and properties of bimetallic rods from oxygen-free copper and electrically conductive aluminum is investigated. Process variables include amount of deformation, tooling geometry, billet composition and disposition of the constituents in the billet. The effect of these variables on the forming loads, interfacial bond strengths, texture, residual stress distribution and metal flow pattern in the deforming region are determined by direct measurements of extrusion pressures, mechanical tests, x-ray, and Moire fringe techniques. The experimental studies are coupled with an analytical investigation of the forming process using incremental, elastic-plastic constitutive laws with strain-hardening for the constituents in a finite element model of the process. This is the second year of a new three-year continuing grant. The first year was supported at SUNY at Stony Brook under DMR80-23158.

42. Stress Corrosion of Stainless Steel

Current Award: 72.6/12/3CR
Effective Date: 7/15/82

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Stress corrosion cracking (SCC) of ferritic and austenitic stainless steels differ in the sensitivity of their cracking potential to interstitial solutes and to thermal/mechanical history. Stepped potential stress corrosion cracking tests will be employed to evaluate the concept that the cracking potential for the ferritic stainless steels is a potential for crack initiation and achieves that for crack propagation as a limiting condition. Composition and thermal/mechanical history are considered to control the degree of occlusion of corrosion cells with the limiting condition arising when the degree of occlusion is sufficient to sustain the active state. Determination of repassivation rates, creep rates and the nature of protective films will be obtained to evaluate these concepts. The ability to restore immunity to SCC of cold worked or grain coarsened low interstitial ferritic stainless steels by appropriate annealing treatments is of considerable commercial importance. The influence of these treatments on cracking will be evaluated to optimize the stress corrosion resistance. Interrupted loading experiments have demonstrated the existence of a hydrogen embrittled zone ahead of cracks in ferritic stainless steels. Such experiments will be continued on both ferritic and austenitic stainless steels in order to clarify the role of hydrogen in the mechanism of SCC. This is a continuation of research previously funded under NSF Grant DMR79-11680. This is the second year of a three-year continuing grant.

43. Solidification Studies of Alloys in Monotectic and Eutectic Systems

Current Award: 64.1/12/3CR
Effective Date: 11/1/81

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This is a fundamental investigation of the solidification of binary and ternary alloys. The objective is to improve the understanding of the mechanisms of isothermal and monovariant reactions. The first area of research involves monotectic reactions in which conditions permit coupled growth. The alloys to be investigated are Al-In, Cu-Pb, Sn-S and In-S. Transparent organic materials will also be studied to more directly observe what happens at the continuous growth front in hypermonotectic alloys. Monotectic alloys Cu-Pb, Al-In, Sn-S and In-S with fibrous composite structures will be examined by X-ray and electron diffraction methods to determine the presence or absence of preferred epitaxial orientations between the phases. Very careful directional solidification studies of cast iron of variable silicon contents will be undertaken to observe the freezing rates and temperature gradients at which there is a transition from grey to white iron. The interfacial under-cooling will also be measured. The morphological and crystallographic complexities of fine graphite will be investigated employing optical, transmission electron and scanning microscopic techniques. This is a continuation of research previously supported under NSF Grant DMR79-08820 A01 at the University of Wisconsin-Milwaukee. This is the second year of a three-year continuing grant.

44. Ductile Fracture and Hydrogen Embrittlement

Current Award: 84.4/12/5CR(C.E.)
Effective Date: 4/15/82

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This is a continuation of a theoretical and experimental study aimed at understanding hydrogen embrittlement effects in plain carbon steels. The following research is underway: (i) studies aimed at clarifying the role of strain gradient in the onset of plastic deformation; (ii) combined permeation and electron microscopy studies to understand unusual observations reported in hydrogen permeation studies in the "damaging" charging regime (i.e., with current densities exceeding 150 amperes/square meter); Professor Hirth has postulated that the unusual permeation flux behavior with increasing charge current density is associated with time dependent dislocation formation (microcreep) and microcrack growth, both of which provide new hydrogen at a constant rate with time; and (iii) testing the author's hypothesis that the observed transition from hydrogen softening to hardening behavior observed in steels is a rate effect associated with hydrogen dislocation interactions, by a series of mechanical load-strain rate experiments. this is a continuation of research previously supported under NSF Grant DMR74-21243 A02. This is the fourth year of a five-year continuing grant. The fourth and fifth yearsof this project are supported under a two-year extension for Special Creativity.

45. Defect Interactions in Metals

Current Award: 83.7/18/42CR
Effective Date: 8/15/81

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Many of the properties of metals are affected or even controlled by the presence of small concentrations of impurities or defects in their crystal structure. The objective of this research is to obtain an increased understanding of impurities and defects and their interactions in metals, and the role they play in determining the properties of metals. The defects will be studied using computer modelling techniques. The physical situation is first described mathematically using a number of adjustable parameters, and then computer experiments are carried out to study the system. As an example, formation and migration energies and configurations of structural point defects such as atoms missing from lattice sites or extra atoms in the lattice will be investigated for the hexagonal close-packed structure, using titanium as a prototype. It is expected that the results of this study will aid in assessing the usefulness of hexagonal metals under conditions of high radiation damage. In general, metals being irradiated have a very rapidly varying distribution of defects, with high defect creation and annealing rates. Slight imbalances between concentrations of different defects can lead to severely altered microstructures and physical properties. As another example of research to be carried out, this variation with time due to radiation damage will be modelled. Here the results should help in the development of better metals for use in possible future breeder or fusion reactors. This is a continuation of research, previously supported by NSF Grant DMR78-07539 A02. This is the first installment on a forty-two month continuing grant.

46. Calculation of Ternary Phase Diagrams by Computer Methods

Current Award: 121.4/12/5CR(C.E.)
Effective Date: 8/1/82

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Calculation of ternary phase diagrams depends upon the definition of lattice stability, solution and compound phase parameters. Pair potential functions are used to compute lattice stability and solution phase parameters on representative isothermal sections of high performance ternary alloy systems, and the results obtained are compared with available experimental data. In addition, the liquidus surfaces will be determined for a series of ternary systems in which the formation of metallic glasses has been observed in specific ranges of composition. Metallic glass formation has been reported for all the ternary systems under investigation (i.e., Fe-Mo-B, Fe-W-B, Ni-Mo-B, Ni-W-B, Co-Mo-B, Co-W-B, Fe-Mo-C, Fe-Cr-C, Mo-Cr-C, Co-Mo-C, Co-W-C and Co-Cr-C). This is a continuation of research previously supported under NSF Grant DMR76-08453 A02. This is the fourth year of a five-year continuing grant. The fourth and fifth years of this project are supported under a two-year extension for Special Creativity.

47. Kinetics of Reactions Between Arc Plasmas and Liquid Metals

Current Award: 60.0/12/2CR
Effective Date: 6/15/82

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This is a fundamental study on the kinetics of N solution from an arc plasma into liquid Fe and Fe alloys. The goal is to elucidate the mechanism whereby hydrogen accelerates desorption and decelerates absorption of nitrogen. Experiments are underway to critically test the postulated reaction mechanism, and to determine the effectiveness of hydrogen as a refining agent for the removal of oxygen, carbon and sulfur. This is a continuation of research, previously supported under NSF Grant DMR80-15499 A01. This is the second year of a two-year continuing grant.

48. Heat Flow and Solidification During the Autogenous Gas Tungsten Arc Welding of Moderately Thick Aluminum Plates

Current Award: 65.3/12/3CR
Effective Date: 5/1/82

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The objective of this program is to determine the effects of welding parameters on heat flow and solidification during autogenous gas-tungsten-arc (GTA) welding of moderately thick aluminum plates. This work will extend previous studies of two-dimensional heat flow and solidification during GTA welding of thin aluminum sheets to a more advanced three-dimensional study involving the welding of moderately thick aluminum plates. The work will include: (1) computer simulation of both heat flow and solidification; (2) temperature measurements during welding experiments; (3) examination of the weld microstructure; and (4) mechanical tests of the weld. The materials to be employed are 2219 and 5083 aluminum alloys. The welding parameters to be considered are the power input, the welding speed, the thickness and preheating of the workpiece. The observed thermal cycles, configuration of the fusion zone and weld microstructure will be compared with those calculated in the computer simulation. It is expected that such a quantitative study of heat flow and solidification will help achieve better control over the structure and properties of fusion welds in aluminum alloys. This is a continuation of work previously supported under a two-year research initiation grant, DMR80-07315. This is the first year of a three-year continuing grant.

49. Deformation Behavior and Structure of Dual Phase Steels

Current Award: 81.4/12/3CN
Effective Date: 4/1/82

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This is a program to determine the relationship between the deformation behavior and the structure of dual-phase steels. These steels have complex microstructures consisting principally of martensite and ferrite, with retained austenite, ferrite-carbide mixtures and precipitates of various types. Alloys will be selected and heat treated to produce martensite in a majority ferrite phase of varying degrees of complexity. The nature and amount of retained ferrite and epitaxial ferrite will be characterized by high resolution optical microscopy and by transmission electron microscopy (TEM). Data from true strain-true stress curves will be used in the Jaoul-Crussard analysis which sensitively monitors the multi-stage strain hardening behavior of these steels. The heterogeneity of the dislocation distribution and the development of the dislocation substructure with increasing plastic strain will be systematically followed by TEM of prestrained specimens. A model of dual-phase deformation behavior will be developed based on features of continuum mechanics models of composite deformation and dislocation accumulation models for plastically nonhomogeneous materials. This is the first year of a new three-year continuing grant.

50. Flow and Fracture in Superplastic Materials

Current Award: 67.1/12/3CR
Effective Date: 6/15/82

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The goal of this investigation is to determine the processes of flow and fracture in superplastic materials (i.e., materials which exhibit neck-free strains of several hundred percent when pulled in tension). Materials under study include the Zn-22%Al eutectoid, the Pb-62%Sn eutectic, the Al-33%Cu eutectic, and Cu-9.5%Al-4%Fe. Research underway includes: (i) analyses of cavity growth, especially using the data from pre-machined holes; (ii) systematic experiments to characterize the details of neck formation and to determine the role of external notches in the localization of plastic flow; and (iii) extension of the concepts developed for two-phase alloys to commercial superplastic materials. This is a continuation of research previously supported under NSF Grant DMR76-16596. This is the third year of a three-year continuing grant.

51. The Effect of Aluminum on the Work Hardening and Wear Resistance of Hadfield Manganese Steel

Current Award: 93.0/12/3CN
Effective Date: 1/1/82

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This is an industry/university cooperative study to determine the effects of aluminum additions on the work hardening and gouging wear resistance of Hadfield manganese steel. In a previous study, it was shown that the work-hardening characteristics of this steel are due to dynamic strain aging produced by the reorientation of Mn-C couples in the cores of dislocations. Others have shown that the gouging wear resistance of this steel increases with carbon content. Therefore, the wear properties of the alloy may be improved, while retaining a tough, single-phase austenite structure, by adding a substitutional solute that lowers the activity of carbon in austenite. The effects of additions of aluminum to the steel will be examined. A series of alloys containing up to 1.75%C and 4% Al will be cast. The work hardening characteristics, high-stress abrasion resistance, gouging abrasion resistance and toughness of the alloys will be determined. Experiments will be performed to measure the effect of aluminum on the activity of carbon in the austenite of Hadfield steel and to determine the rate of precipitation of carbides from solid solution. This is the first year of a new three-year continuing grant.

52. The Stability of Amorphous Metals in Corrosive Environments

Current Award: 110.2/18/42CR
Effective Date: 9/1/81

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This is a continuation of an investigation to understand the resistance of amorphous metallic materials to general and localized corrosion (GALC) and to environmental embrittlement. On-going research to define the role of structure (crystalline versus amorphous) and composition (metalloids such as P, film formers) on GALC characteristics will be extended to determine the role and effect of the amorphous substrate on film growth kinetics (anodic and cathodic) of glassy alloys containing film-forming elements, before and after devitrification. Materials under study will include Fe-Ni-Cr-P-B, Fe-Ni-P-B, Ni-P, Ni-Si-B and Cu-Zr-P alloys. In addition, hydrogen permeation and embrittlement studies will be undertaken in glasses containing hydride forming elements (Cu-Zr and Cu-Zr-P) and with a lower void density in glassy and devitrified condition to determine if hydrogen embrittlement is a generic characteristic of transition metal-metalloid glasses or a correctable consequence of fabrication. The influence of Cl^- ions and caustic environments will be investigated to assess the significance of the surface film at shear bands on the tendency towards stress corrosion cracking at anodic potentials. Lastly, the GALC resistance and susceptibility to stress corrosion cracking of surface-modified austenitic stainless steels and copper-base alloys will be determined. This is a continuation of research, previously supported by NSF Grant DMR78-05712 A01. This is the first installment on a forty-two month continuing grant.

53. Continuous and Discontinuous Phase Transformations in Age-Hardening Alloys

Current Award: 81.9/14/38CR
Effective Date: 9/1/81

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This is a fundamental investigation of diffusion controlled phase transformation in age hardening alloys. Research to date has focused on understanding the mechanisms of formation of various metastable phases responsible for precipitation hardening of Ni-based alloys. Mechanisms of ordering and phase decomposition have been investigated by transmission electron microscopy (TEM). Concomitant deformation mechanisms were determined for systems that order. Differential scanning calorimetry (DSC) was also used to document the existence of transition phases and to obtain information about their solvi. During the next three years, studies of continuous phase transformations using DSC and TEM will be extended to Cu and Al-based binary and ternary alloys. In addition, heterogeneous grain boundary reactions (known to promote embrittlement and overage age-hardening alloys) will be investigated using analytical TEM and DSC to understand the role of such variables as grain boundary structure, and segregation of major and minor solute atoms to the boundary. It is expected the results of this research will enhance understanding of continuous and discontinuous transformations in age-hardening alloys, and will serve as a basis for their control in commercial alloys. This is a continuation of research previously supported by NSF Grant DMR78-05723 A02. This is the first year of a three-year continuing grant.

54. Mechanical Properties of Amorphous Materials

Current Award: 75.5/12/3CR
Effective Date: 7/1/81

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This is a continuation of a basic investigation of microstructural mechanisms involved in the deformation and fracture of amorphous materials. In particular, mechanical properties of amorphous metallic materials (e.g., Pd-Si, Fe-Ni-P-B, Fe-B), amorphous polymers (e.g., polystyrene, polycarbonate, polymethylmetacrylate), inorganic glasses, and amorphous Se, Se-Te will be determined. This study includes: an analysis of stored energy in slip bands and associated recovery kinetics, density measurements of deformed materials as a function of strain and recovery, electron microscopy examinations of radiation damage, diffusivity measurements of atomic species in the amorphous state, analysis of crystallization kinetics as a function of density, and laser probing of diffusive mechanisms. Experimental techniques to be employed include: electron and optical microscopy, differential scanning calorimetry, surface profilometry, standard mechanical testing, high voltage electron irradiation, high energy particle irradiation (Van De Graaff accelerator), and a variety of dimensional measurement methods. It is expected the results of this investigation will contribute to an understanding of the defect mechanisms associated with deformation, recovery and crystallization processes in amorphous materials, and document the activation energies of various atomic rearrangement processes in amorphous materials. This research was previously supported under NSF Grant DMR76-01992. This is the third year of a three-year continuing grant.

55. Fundamental Studies of Passive Films on Metals and Their Breakdown

Current Award: 141.0/36/3N
Effective Date: 7/15/79

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This investigation will develop predictive theories of passivity for explaining the effects of alloying and environmental influences. The approach utilizes surface analysis techniques to completely characterize passive films and to determine the major compositional and electronic properties associated with stability and instability. Definitive experiments will be performed to rationalize the mechanism of chemical breakdown, to assess the importance of the electronic properties of passive films on their stability, and to determine whether passivity can be attributed to the presence of a chemisorbed monolayer film whose protective properties change with alloying or to a three-dimensional film. The investigations utilizing surface analysis techniques (Auger electron spectroscopy, x-ray photoemission, and secondary ion mass spectrometry) will be facilitated by a unique electrochemical cell which can be operated in an ultra-high vacuum system. The investigations will focus on the Fe, Fe-Cr, Fe-Cr-Mo, and Fe-Si systems exposed to $1NH_2SO_4$ (pH 8.4 borate buffer solutions with and without Cl^- will be utilized in some cases) and NaCl solutions. These systems have been chosen because they represent model, iron-base systems which are building blocks for more complex structural alloys, and are known to exhibit several different types of beneficial alloying effects: (i) Critical concentrations of approximately 12% Cr and 14.5% Si in iron binaries where precipitous changes in stability occur; (ii) A synergistic interaction between silicon and chromium which reduces the critical silicon concentration by a factor of five in stainless steels; and (iii) A synergistic interaction between molybdenum and both chromium and silicon to give substantial improvements in passive film stability particularly in chloride environments. This is the third year of a new three-year industry/university cooperative research program.

56. Interatomic Potentials to Study Physical Phenomena in Alloy Systems

Current Award: 80.8/12/3CR
Effective Date: 7/1/82

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Interatomic potentials developed for alloys are used to computer simulate the segregation to grain boundaries in body-centered-cubic and face-centered-cubic iron of certain interstitial solutes (O,C). Computer simulation of a tensile test across various segregated grain boundaries is conducted to evaluate the ideal fracture work of segregated and non-segregated grain boundaries. The effect of electronegativity difference on the synergistics of grain boundary segregation and structure for ternary alloys is being evaluated via computer simulation. Improved lattice energy functions are being developed that can facilitate computer simulation of defects in alloys and can be used to determine the effect of quadrupole polarizability upon grain boundary structure and segregation parameters in alloys. The possibility of predicting phonon dispersion curves for homoelectronic alloy phases is being evaluated. Similarly, the possibility of predicting phonon dispersion curves for transition metal (T)-sp element (X) alloys is being evaluated. Current emphasis is on: (i) defining alloy phases that have soft phonons and high densities of states (hence, have potential for high superconducting critical temperature); (ii) simulation of segregation to grain boundaries to determine factors affecting such segregation and the effects of such segregation on two-dimensional grain boundary structures; and (iii) evaluation of possible mechanisms of grain boundary decohesion. This is a continuation of research previously supported under NSF Grant DMR77-08667 A02. This is the third year of a three-year continuing grant.

57. Grain Boundary Contribution to the Bauschinger Effect and Slip System Criteria

Current Award: 59.6/12/3CR
Effective Date: 1/1/82

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This is primarily an experimental study of the origin of the Bauschinger effect in crystalline materials. The Bauschinger effect is a lowering of the stress required for initiation of plastic deformation in the reverse direction after straining in the forward direction. The effect of grain boundaries on the effect is being studied in bi and tricrystals of beta-brass by determining the inhomogeneous distribution of strain at the boundaries compared to that in the bulk of the crystal. The residual stress level at the boundaries has been estimated to be at least twice that in the bulk after unloading from a tensile stress. A quantitative determination of the grain boundary zone contribution to the effect is being made. The research is also being extended to determine the stress levels at grain boundaries in polycrystalline materials with relatively large grains. Grain orientations, slip systems and critically resolved stresses are being determined in boundary regions. It is expected that the research will resolve the following: (1) the role of plastic incompatibility on slip at grain boundaries; (2) why the high Schmid factor slip systems do not operate; and (3) whether six strains need to be considered for the operation of a slip in a surface grain at the center of the specimen. This is a continuation of research previously funded under NSF Grant DMR77-04118 A02. This is the second year of a three-year continuing grant.

58. Computer Simulation of Hydrogen Effects on Mechanical Properties of Metals

Current Award: 53.1/12/3CR
Effective Date: 5/15/81

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Computer simulation techniques are being used to model the effects of hydrogen on mechanical properties of both the brittle and ductile phases of iron. Atomic level properties being studied include the interaction of hydrogen with lattice defects, such as cracks, dislocations, and surfaces under conditions of externally applied stress. Results are being interpreted in terms of macroscopically observed effect of hydrogen on mechanical properties. A critical evaluation is being carried out on existing Fe-H interatomic potentials. Simulation codes are being developed to provide a more physically realistic description of atomic level phenomena occurring within the bulk of a macroscopic crystal, including: (i) a new technique to determine saddle-point configurations; (ii) an analytical method of crack extension by kink propagation; and alternative techniques to obtain hydrogen-metal interaction potentials for transition metals. This is a continuation of research previously supported under a two-year standard grant, DMR78-05714 A02. This is the third year of a three-year continuing grant.

59. Phase Diagram Basis in the Study of Glassy Alloys

Current Award: 63.0/15/39CR
Effective Date: 8/1/81

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The objectives of this investigation are to determine: (i) the phase stability factors which promote deep eutectic formation in multicomponent metallic glass systems, and their relationship(s) to electronic structure and size differences between the participating component atoms; and (ii) the relationship(s) between deep eutectic compositions in ternary glassy alloy systems and their potential glass-forming ability. The approach involves an initial slow solidification of selected alloys, followed by microprobe studies of the resulting microstructures. Promising new deep eutectic alloys will be further investigated for potential metallic glass-forming ability, employing the usual techniques of rapid solidification, followed by diffraction and calorimetry experiments. The research will be done on Cu-based ternary alloys, including Cu-Te-Ge, Cu-Mg-Ca, Cu-Ag-In, Cu-Mg-In and Cu-Mg-Zn. It is expected that the results of this investigation will enhance understanding of the relationships between rapid solidification, deep eutectics and metallic glass formation. This is a continuation of research previously supported by NSF Grant DMR78-01581 A02. This is the first installment on a thirty-nine month continuing grant.

60. Thermodynamics and Kinetics of Interstitial Solid Solutions

Current Award: 84.2/18/42CR
Effective Date: 8/15/81

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This is a continuation of a theoretical and experimental investigation of the thermodynamic and kinetic behavior of interstitial atoms in one-component, binary and ternary metallic systems. The thermodynamic functions (partial enthalpies and entropies) of interstitial solute atoms in metals and solid solutions of two metals will be determined as a function of both temperature and composition. Also, the diffusivity of the interstitial species in the solvent will be measured. The data will be used to evaluate theoretical models for binary and ternary interstitial solid solutions. The main thrust of the measurements will center on nitrogen as the interstitial species, but work will also be performed on hydrogen-metal systems. In addition to this, theoretical projects will be undertaken to study the effects of volume changes on the thermodynamic behavior of solutions, the interactions between interstitial solutes and lattice discontinuities, and anomalous temperature variation in the elastic constants of various metals. Additional measurements of the temperature variation of single-crystal elastic constants will also be made. This is a continuation of research, previously supported by NSF Grant DMR78-01306 A02. This is the first installment on a forty-two month continuing grant.

61. The Effects of Impurities, Including Hydrogen, on Intergranular Cohesion in Iron-Based Alloys

Current Award: 96.3/12/3CR
Effective Date: 4/15/82

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The goal of this research is to understand the effects of various segregated impurities on intergranular cohesion in ferrous alloys. The intergranular fracture stress is being measured as a function of grain boundary composition in several series of Fe-Si alloys containing P, Sn, Sb, etc. The experiments are done on notched polycrystalline specimens and on smooth and notched bicrystals. Auger electron spectroscopy is used to determine the intergranular composition. In conjunction with these experiments, further development of a brittle fracture theory to estimate changes in intergranular cohesive energy (ideal work of fracture) from the fracture stress measurements is underway. This is a continuation of research, previously funded under NSF Grant DMR78-07535. This is the second year of a thirty-eight month continuing grant.

62. Study of Family of Chromium-Free, Rust Resistant and Oxidation-Resistant Steels

Current Award: 159.6/36/3N
Effective Date: 3/15/80

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Preliminary work has identified a family of Cr-free steels in the system Fe-Si-Mn-Ni-C which have a unique combination of desirable properties; ease of formability; high strength; and very good oxidation and corrosion resistance. The goal of this project is to establish the scientific basis for alloy design in terms of optimum alloy compositions and processing conditions. The research includes: (i) analysis of phase equilibria and transformations in the composition ranges appropriate for austenitic structures; (ii) analysis of the crack initiation characteristics of mixed austenite-ferrite structures; (iii) analyses of the conditions of passivity and the nature/characteristics of the passive film; and (iv) determination of the high temperature reactions with aggressive gas components. Particular emphasis is placed on the role of Si in film formation and the role of C in solid solution. This research is in the third year of a new three-year standard grant.

63. Simultaneous In-Situ Investigation of Defect Production by Electron Microscopy and Electrical Resistivity

Current Award: 220.0/38/R
Effective Date: 9/1/81

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A technique has been developed, for the first time, to combine high-voltage electron microscope observations and electrical-resistivity measurements for a simultaneous in-situ invesigation of defect production and reaction in metals under the influence of electron and/or ion irradiation. This technique has been used to determine the displacement threshold energy surface in copper. By taking advantage of two observation methods, the technique has eliminated major ambiguities present in other experiments of this type and has provided the most consistent threshold energy surface that is available. The results indicate that significant modification may be necessary in the accepted picture of defect production. This technique is also being used to determine the efficiency of various interstitial sinks and has revealed a substantial difference in the efficiency between interstitial clusters and dislocation loops. This is a continuation and extension of the present technique to investigate the temperature dependence of the displacement threshold surface, the efficiency of interstitial sinks and the displacement threshold surfaces of aluminum, silver and other face-centered-cubic metals. This is a continuation of research, previously supported by NSF Grant DMR77-14990.

64. Martensitic Transformation Induced by Tensile Stress Waves

Current Award: 79.7/12/3CN
Effective Date: 4/1/82

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This is a program to study martensitic transformations induced in ferrous alloys by tensile stresses. A tensile hydrostatic stress pulse, generated by shock-wave reflection at a free surface, will provide conditions from which the nucleation time for athermal martensite can be determined. A gas gun will be used to carefully control the stress pulse; the pulse parameters will be determined using manganin piezoresistive measuring gages with Lagrangian computer codes. Gas-gun experiments will be conducted at the Shock Physics Laboratory of Stanford Research Institute, a sub-contractor, and the Principal Investigator will work in close contact with their staff. In the first two years of the program, simple Fe-Ni and Fe-Ni-C alloys will be systematically investigated. More complex systems—possibly including rapidly-solidified Fe-Ni alloys—and the interactions with and implications of spallation will be explored in the third year. It is expected that this research will provide added understanding of the nature of athermal martensitic transformations. This is the first year of a new three-year continuing grant.

65. Diffusion Driven Boundary Motion in Alloys

Current Award: 103.8/18/42CN
Effective Date: 8/1/81

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A new and poorly understood driving force for grain boundary motion in alloys has recently been discovered, herein termed Diffusion Driven Boundary Motion (DDBM). DDBM might play a controlling role in determining when systems undergo discontinuous precipitation and provides a means of determining the diffusion coefficients in moving boundaries. This project will initially examine several systems in an effort to establish the nature and magnitude of one force causing DDBM. A new analysis is presented which indicates how the boundary diffusivities of the two species in a binary alloy can be obtained from measurements of surface relief and dimensional changes in the plane of a foil. DDBM in a wide range of copper and iron terminal solid solutions will be studied by depositing a thin film of solute on the surface and then annealing for various times and temperatures below half the melting temperature. This will allow studies of surface relief and estimates of the driving force to be made. Systems exhibiting discontinuous precipitation will be studied first, but not exclusively. Initial studies will be made on binary alloys of Cu-Ag, Au, Sn, Cd or Sb and Fe-Zn, Sn or Sb. The activation energy of DDBM will be investigated using foil specimens, temperature jumps, and a capacitance-torsion balance developed here. This will be done after the systems which exhibit DDBM over the largest fraction of their volume and the time dependence of the motion have been identified. This is the first installment on a new forty-two month continuing grant.

66. Theoretical Elastic Behavior of Crystals at Large Strains

Current Award: 51.9/12/3CN
Effective Date: 7/1/82

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This is a theoretical investigation of large strain elasticity of perfect single crystals, using the formalisms of pseudopotential theory. In particular, calculations are underway to determine the path dependencies of the mechanical load, the stress, the lattice parameters/lattice strain, and the elastic moduli of crystals for various modes of mechanical loading, including various shear loads. In addition, criteria will be formulated and generalized to describe the elastic stability of crystals under load. This research is done in collaboration with Professor Rodney Hill of Cambridge University. This is the second year of a new three-year continuing grant.

67. Creep Behavior Under Very Low Stresses

Current Award: 55.7/12/3CR
Effective Date: 6/15/82

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Experimental evidence indicates the occurrence of two Newtonian processes, Nabarro-Herring creep and Harper-Dorn creep, at very low stresses and at temperatures near the melting point. The creep strain of the Nabarro-Herring process is produced by vacancy transport, and the steady-state creep rate, which is governed by lattice diffusion, is dependent on the grain size of the material. In contrast, the creep strain ascribable to Harper-Dorn creep is produced by some form of dislocation activity in the grain size. The objectives of this program are: (i) consolidate the present substructural results on Harper-Dorn creep in aluminum and its alloys; (ii) investigate the relationship between the Harper-Dorn process and Nabarro-Herring creep; (iii) study the effect of the stacking fault energy on the normalized creep rates of the Harper-Dorn process; and (iv) examine Harper-Dorn creep as a general process of deformation. This is a continuation of research previously funded under NSF Grant DMR80-05976 at the University of Southern California. This is the third year of a three-year continuing grant.

68. Growth Coarsening of Dendrites in Binary Alloys

Current Award: 51.8/12/3CN
Effective Date: 8/1/82

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The goals of this investigation are: (i) to characterize the solidification conditions as they exist across the mushy zone of a binary alloy during directional solidification; (ii) to relate the growth and coarsening of the dendrites to the solidification conditions; and (iii) to model the observed dendrite formation in terms of the solidification conditions. Investigations are being performed on Cu-10%Fe alloys which are directionally solidified at constant velocity and then quenched to freeze in the mushy zone structure. The mushy zone is characterized by optical microscopy, scanning electron microscope and microprobe analysis. A theoretical model to describe supersaturation in interdendritic pools has been developed, and is being assessed with experimental data obtained. A new study is currently underway, to model growth and coarsening behavior inside the outer envelope of the dendrite periphery. The composition maps and measured coarsening kinetics suggest that a simple model can be developed to describe microstructural evolution across the mushy zone, and to predict the final dendrite arm spacings as a function of alloy and processing parameters. This is the third year of a new, three-year continuing grant.

69. Mechanical and Microstructural Aspects in Superplasticity and Creep

Current Award: 68.4/12/5CR(C.E.)
Effective Date: 6/15/82

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Metallic materials with stable, equiaxed fine grained structure can be deformed at elevated temperatures to exceptionally large strains without risk of rupture. This phenomenon, termed superplasticity, is associated with extensive sliding along the grain boundaries. Two current theoretical models for superplasticity suggest that the sliding in polycrystalline materials is accommodated either by diffusional flow or by dislocation motion in regions in or adjacent to the boundaries. However, there are several major discrepancies between experimental results and the prediction from these models. The objectives of this investigation are: (i) to clarify the microstructural changes that occur during superplastic deformation; (ii) to investigate the anomaly regarding activation energy and the role of the threshold stress; (iii) to delineate the range of operation of the superplastic process; and (iv) to examine in detail the criteria for transition from superplastic to creep process at higher stresses, and to study the activation parameters for the latter mechanism. Emphasis during the last two years of this study has been placed on advanced aspects of cavity nucleation studies, the role of grain boundary sliding in cavitation, and the effect of precipitates on the cavitation process. The material used for this project is a very high purity, very low interstitial content, two-phase Ni-base powder metallurgy alloy processed to produce a fine, stable and equiaxed grain microstructure. This is a continuation of research previously supported under NSF Grant DMR76-11630. This is the fifth year of a five-year continuing grant. The last two years of this program have been supported under a two-year extension for Special Creativity.

70. Time Dependent Plastic Flow in Metals and Alloys

Current Award: 69.2/12/3CR
Effective Date: 6/15/82

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This is an investigation to determine basic mechanisms of time dependent plastic deformation of metallic materials. The underlying theme of this project is that two kinds of laws are needed to describe time dependent flow: a kinetic law which describes plastic flow for a fixed structure, and a structure evolution law. Anelastic creep experiments will be done for Al and Al-Mg solutions in order to characterize the nature of the deformed state, to characterize its time evolution during creep, and to determine kinetic law behavior. A newly developed high resolution creep apparatus is employed in which linkage displacements are excluded from the measurements, and the experimental focus is on instantaneous strains associated with stress changes. Several experiments are underway to elucidate the mechanisms of dynamic recovery in metallic materials. These include studies on: anomalously fast creep after a large stress reduction in Al with special reference to the temperature dependence of this kind of flow; the mechanisms of strain softening in LiF to determine the relative importance of primary and secondary dislocations in that process; strain softening in Ni-Co solid solution alloys to determine the dislocation processes associated with dynamic recovery; and steady state flow properties of Ni-Co alloys to determine the effects of stacking fault energy on the nature of power law breakdown. This is a continuation of research previously supported by NSF Grant DMR79-23942, and is the first year of a three-year continuing grant.

71. Martensitic Deformation Under Cyclic Stress

Current Award: 58.8/12/5CR(C.E.)
Effective Date: 12/15/81

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This is a fundamental study of the isothermal stress/strain behavior of alloys which exhibit no, partial, or complete thermoelastic growth behavior on thermal cycling. The objective is to understand the relative magnitudes of the work required to: (i) move various types of parent/martensite interfaces; (ii) produce plastic accommodation strains; and (iii) nucleate new plates and, thereby, obtain an insight into the cyclic stress/strain behavior of these alloys. The systems under study include Fe_3Pt, Fe-Ni-C and/or Cu-Al-Ni. Smooth bar fatigue tests will be run to failure, when possible. An attempt will be made to identify the fatigue crack initiation mechanism operative in each case by studying the fractures microscopically and with scanning electron microscopy. In addition, advanced theoretical and experimental studies are underway on the motion of single martensitic interfaces as a function of composition and strain rates in Cu-Al-Ni crystals, as well as a new study aimed at understanding dynamic precipitation and recrystallization phenomena which occur during hot compression of microalloyed steels. This is a continuation of research previously funded under NSF Grant DMR74-22719 A02. This is the fourth year of a five-year continuing grant. The fourth and fifth years of this study are supported under a two-year extension for Special Creativity.

72. Analyses of Grain Boundary Segregation Using Extended X-Ray Absorption Structure

Current Award: 66.3/12/3CR
Effective Date: 8/15/81

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This is a fundamental investigation of grain boundary segregation phenomena in Fe and Ni-Cr alloys. Extended x-ray absorption fine structure (EXAFS) techniques are employed to determine changes in local atomic arrangements during segregation and/or embrittlement, as a consequence of the presence of trace impurity elements, primarily Sn. Research underway includes: (i) extension of analysis procedure to obtain nonlinear least square fits to known structures on the data already obtained on segregated Sn in Fe; (ii) use of intergranular diffusion techniques to prepare alloy steel specimens with Sn impurities at the grain boundaries but not in the matrix; (iii) extension of EXAFS measurements to investigate the segregation of Sn in Ni-Cr alloy steels, with emphasis on Ni-Sn interactions; and (iv) feasibility experiments to assess the applicability of a complementary surface spectroscopy for these studies, the fine structure in appearance potential spectroscopy, on the same materials. This research was previously supported by NSF Grant DMR77-24499. This is the first year of a three-year continuing grant.

73. Stability of Carbides in Alloy Steels and Resistance to Hydrogen Attack

Current Award: 57.1/12/32CN
Effective Date: 4/15/82

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Hydrogen is known to damage steel in two ways, by hydrogen embrittlement (hydrogen-induced brittle fracture) and by hydrogen attack (formation of fissures and blisters in steels after exposure to hydrogen at elevated temperatures). Hydrogen attack (h.a.) is caused by non-diffusing methane formed from H and C in a ferrite matrix. The methane accumulates in nucleation sites and fissures which eventually expand, causing material failure. Thus, carbide stability (c.s.) has an important influence on susceptibility to h.a. of steels. The objective of this investigation is to clarify the relationship between the stability of carbides in low alloy steels and the resistance of the steels to h.a. Concentrations of C and alloying element M (where M is Cr, Mo, Ti, V, Nb) in steel equilibrated with CH_4/H_2 mixed gases of fixed composition will be measured from 500 to 750°C. From these data, the standard free energies of formation will be determined for Cr-, Mo-, V-, Ti- and Nb-carbides coexisting with cementite in a ferrite matrix. Metastable carbides as well as those in equilibrium will be examined. From this thermodynamic information, c.s. will be evaluated and correlated with h.a. resistance. This is the second year of a new thirty-two month continuing grant.

74. Nucleation Kinetics and Thermodynamics of the Liquid-Solid Transformation

Current Award: 73.1/12/5CR(C.E.)
Effective Date: 11/1/82

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This is a fundamental investigation of undercooling and nucleation during the liquid-solid transformation utilizing the droplet-emulsion technique. The primary objective is to understand the details of the liquid-solid transformation at high undercooling. The materials under study include Pb, Bi, Sn, In, Ga, Hg and binary alloys thereof. In addition, the drop emulsion technique is used to study elemental Cd, Zn, Li, or Na. The maximum undercooling is determined by differential thermal analysis, and the nucleation rates are measured by differential scanning calorimetry. To complete the analysis of the nucleation measurements, the specific heat of the metastable undercooled liquid state of the metals will be determined. In addition, in alloy emulsions that have proven to exhibit a high undercooling, the catalytic effect of known heterogeneities, such as primary phase crystals, on nucleation are examined without the possible interference of substrate material. Advanced techniques of droplet-emulsion are being developed to allow investigation of a wider selection of metals and catalytic particles (such as oxides), and to examine superheating phenomena in solids. It is expected the results of this investigation will enhance understanding of undercooling and nucleation of liquid metals, determine the conditions for homogeneous volume dependent nucleation, define the thermodynamic properties of the metastable undercooled liquid state, provide an improved comprehension of the factors which determine nucleation catalysis in alloys, and serve as a basis for critically assessing theories of nucleation catalysis and homogeneous nucleation rate kinetics. This is a continuation of research previously supported under NSF Grant DMR77-13932. This is the third year of a three-year continuing grant. This project was recently approved for a two-year extension for Special Creativity.

75. Martensitic Transformations in Shape Memory Alloys

Current Award: 50.7/12/30CN
Effective Date: 5/1/82

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The objective of this research is to investigate the effect of microstructural parameters on martensitic transformations in shape memory alloys. The major microstructural variables to be examined include austenite grain size, grain boundary structure, dislocation substructure and parent phase strength. Effects on the martensitic transformations will be evaluated in terms of the crystallography of the transformation, morphology, transformation temperature, reaction kinetics, and shape memory behavior. Experimental techniques that will be used to characterize the microstructure and monitor the transformations include x-ray diffraction (to determine crystal structure), scanning electron microscopy (to evaluate grain size and shape and the general distribution of microstructure), transmission electron microscopy (to observe the fine structure of the martensite and austenite phases), differential scanning calorimetry (to detect transformation temperature ranges), microhardness (to measure phase strengths), and tensile testing (to characterize shape memory behavior). Novel aspects of the experimental program include the use of rapid solidification to produce very fine-grained samples, controlled grain-size variations over a wide range, and in-situ SEM studies of shape memory parameters as a function of thermomechanical history and microstructure. This is the second year of a new thirty-month continuing grant.

76. A Fundamental Study of Liquid Phase Enhanced Creep

Current Award: 55.8/12/3CN
(27.9 from Ceramics, and 27.9 from Metallurgy)
Effective Date: 7/1/82

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This is a study of the mechanisms by which a small amount of a liquid phase in a material which is otherwise solid can increase the rate at which it creeps. Liquid phase enhanced creep is observed in a number of materials, including structural ceramics containing a glassy boundary phase which drops sharply in viscosity at high temperatures and alkali halide salts containing saturated brine. It is also believed to be a dominant deformation mechanism in many geophysical systems. Primarily due to a lack of good experimental data to quantify it, the mechanisms which control liquid phase enhanced creep are not well understood. The intent of this research is to overcome this lack of understanding by extensively characterizing liquid phase enhanced creep in model materials. Under current investigation are compacted potassium chloride with saturated KCl solution and aluminum alloys with a low melting point alloy second phase. Metallic systems in which it is possible to freeze in the liquid phase following creep at elevated temperatures are being investigated so that its distribution in the solid can be examined using metallographic techniques. This information is being used in the study to develop better theoretical models for liquid phase enhanced creep. This is the first year of a new, three-year continuing grant.

77. Orientation Relationships and Interface Structures in Cast Irons

Current Award: 40.0/24/2N
Effective Date: 5/15/80

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Cast iron is the most widely used material in the as-cast condition. The mechanical properties of cast iron are determined largely by the size and shape of its graphite particles. Ductile cast iron (containing graphite spheres) is generally stronger than gray cast iron (containing graphite flakes). It is known that Mg and Ce control graphite morphology, but there is little understanding of the interface structure resulting from chemical additives. The goal of this research is to characterize the structures of interfaces produced in cast irons wih various additives using transmission electron microscopy in order to better understand mechanisms of graphitization. This is a two-year research initiation grant.

78. On Preferential Removal of a Component from a Binary Alloy

Current Award: 58.1/12/3CR
Effective Date: 12/15/81

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The goal of this investigation is to understand preferential removal (PR) of a component from an alloy, with emphasis on the nature of the surface instability and the role of the lattice vacancy. Model PR systems are being investigated over a broad temperature range extending down to those of aqueous solutions. Co-Pt and/or Cu-Pt alloys are reacted with HCl gas at elevated temperatures for studies of the surface instability and transport processes. Reaction rates are determined by the thermogravimetric technique; geometrical aspects of the pore structure by scanning electron microscopy; and reaction-produced composition gradients by Auger electron spectroscopy, the electron microprobe, and the atom probe. In order to confirm the previously observed vacancy effect, Cu-Zn and/or Cu-Au alloys are dissolved in acid under controlled electrochemical conditions following quenching, and the extent of PR is determined. Attempts will be made to measure vacancy concentrations by field ion microscopy. It is expected that the roles of alloy composition and vacancy concentration on reaction rate, and on the scale and composition of the pore structure will be elucidated, thereby constituting a significant advance in our understanding of PR. This is a continuation of research, previously supported under NSF Grant DMR77-09371 A02. This is the second year of a three-year continuing grant.

79. The Effects of Interphase Boundary Structure on the Kinetics of Precipitate Coarsening

Current Award: 59.9/12/3CN
Effective Date: 4/15/82

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This is a study of the effects of interphase boundary structure on the kinetics of precipitate coarsening. Existing theories have viewed the coarsening process as either interface reaction limited or volume diffusion controlled and have not been concerned with the actual mechanisms of atomic attachment and detachment or why a given mechanism should be rate controlling. A new model of ledge migration controlled coarsening along with another new and simple coarsening model, will be thoroughly examined in this investigation. Both shape and size precipitate coarsening in three alloy systems will be studied: i) θ and θ' precipitates in Al-Cu; ii) gamma precipitates in Al-Ag; and iii) Cu precipitates in Fe-Cu. Thus, in addition to the usual measurements of particle size and particle-size distribution, the interledge spacing and aspect ratios of the precipitates (where applicable) will be determined as a function of aging time. Information about the actual values of these two latter parameters and how they vary with time is critical for testing the new coarsening models. These measurements will be made primarily through scanning electron and transmission microscopy. Experiments will be designed so that the relative importance of ledge migration controlled coarsening can be determined. It is expected the results of this research will enhance understanding of the role of interfacial structure in coarsening, as well as in other phase transformations. This is the first year of a new three-year continuing grant.

80. Permeability and Flow of Interdendritic Liquid in Solidifying Alloys

Current Award: 58.3/12/3CN
Effective Date: 8/1/82

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Gravity causes flow of interdendritic liquid in the solid plus liquid region of an ingot or casting, and such flow is responsible for most of the macrosegregation which is observed in alloys. Prior to 1970, positive segregation in the interior of ingots or in large castings and severe localized segregates (usually called "A-segregates" or "freckles") could not be explained until the extent of gravity-driven flow was documented. Since 1977 the above macrosegregation theory has been applied to show the relationship between solidification rate and macrosegregation, to predict "A-segregates" and "freckles," to model macrosegregation in multicomponent alloys, to control macrosegragaton by rotation, and to show additional momentum- and energy-transport phenomena can be incorporated to refine the basic theory. A major component of macrosegregation theory has been the utilization of D'Arcy's Law to the solid plus liquid region. As such, the dendritic network is treated as a porous solid with a permeability for convection of the interdendritic liquid. The objectives of this study are to measure permeability in solidifying alloys and to determine how permeability depends on: (1) dendrite morphology (primarily dendrite-arm spacings); (2) volume fraction of liquid within a solid plus region; and (3) alloy composition. This is the first year of a new three-year continuing grant.

81. Effects of Dislocation Dissociation and Dislocation Core Structure on Plastic Flow in Pure Metals and Ordered Alloys

Current Award: 105.6/12/3CN
Effective Date: 8/1/82

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This is a theoretical and experimental project to determine how detailed dislocation behavior influences plastic flow in pure metals and long-range ordered (LRO) alloys. The theoretical research, employing computer simulation techniques, includes analyses of: (i) the stability of generalized stacking faults on various crystallographic planes in long range ordered alloys; and (ii) dislocation core structure in various long range ordered alloys for the following situations: (a) screw and edge dislocations on various planes as a function of anti-phase-boundary energy; (b) cross slip of super-dislocations; and (c) dislocation-core configurations under the influence of applied shear and uniaxial stresses. The experimental study includes experiments on the effects of orientation of the tensile and compressive axes on the temperature dependence of the yield stress. Materials under study include close-packed face-centered-cubic alloys (such as Cu_3Au), Co-Fe-Va single crystals, and $Ni_3(Al, Nb)$ single-phase crystalline materials in different orientations, and non-close-packed body-centered-cubic materials (such as βCuZn). It is expected that the results of this research will enhance understanding of the plastic behavior of ordered alloys, and contribute toward a general understanding of the conditions under which the dislocation core structure influences the overall mechanical behavior of metallic materials. This is the fourth year of a new five-year continuing grant, the fourth and fifth years of which are supported under a two-year extension for Special Creativity.

82. Changes in Surface Microstructure of Superalloys Caused by Ion Implantation

Current Award: 80.0/12/3CN
Effective Date: 7/15/82

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This is a study of microstructural changes occurring during ion implantation of two alloys: Ni-12.7at.%Si and Ni-12.8at%Al. The alloys contain the ordered gamma-prime phase and serve as prototypes for more complex superalloys used commercially. The implantation response of these alloys at temperatures below 400°C, temperatures of interest for commercial implantation designed to modify surface chemistry and properties, is not known. This research is aimed at elucidating the basic mechanisms leading to microstructural changes in the temperature range. In particular, the morphological stability, during implantation, of gamma-prime particles existing prior to implantation, and the disordering-effect of the implantation on ordered phases are being examined. Transmission electron microscopy is used to investigate size, shape and distribution of gamma-prime particles as altered by the ion implantation and also, in combination with optical property changes,to investigate the disordering effects of solvent-ion implantation. On completion of this work, the effect of foreign ion implantation ($^{27}Al^+$, $^{28}Si^+$, $^{52}Cr^+$, $^{48}Ti^+$, and $^{56}Fe^+$) is being investigated. Enhanced understanding of the basic microstructural mechanisms operating during implantation is useful in interpreting surface property changes in implanted samples and provides guidelines for design of process conditions (e.g., implantation temperature, ion flux) under which future commercial implantations should be performed. This is the third year of a new three-year continuing grant.

83. Activation Parameters of Cyclic Deformation

Current Award: 78.0/24/2N
Effective Date: 4/15/80

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This is a fundamental investigation of mechanisms contributing to fatigue failure of high purity polycrystalline aluminum. The specimens are cycled in fully reversed plastic strain controlled fatigue to a cyclically stable (saturated) state at strain rates from 10^{-2} to 10^{-5} per second, and temperatures from 300° to 800°K in an ultra low dew point nitrogen atmosphere. Data obtained from these experiments, and other available data on Cu, are evaluated using a newly developed theory of stress and structure change which occurs during fatigue of crystalline metallic materials. For selected strain amplitudes and the above temperature range, information for thermally activated analysis is obtained by stress relaxation techniques, by strain rate cycling experiments, and by experiments involving annealing under stress, on samples containing cyclically stable dislocation structures. From these experiments, and in-situ transmission electron microscopy studies it is possible to separate and identify activation parameters associated with specific dislocation mechanisms. Lastly, the shape of the equilibrium hysteresis loop is examined as a function of strain amplitude, strain rate and temperature, and the results obtained used to examine and possibly modify a theory on equilibrium loop shapes, to include temperature and strain rate as explicit variables. This is a new two-year standard grant.

84. The Hot Corrosion of Metals and Alloys by Fused Salts

Current Award: 105.9/12/3CR
Effective Date: 8/1/82

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This is a study to determine mechanisms of hot corrosion (i.e., material degradation beneath thin salt films in multicomponent oxidant gas environments). More specifically, the acid-base character of fused salts (Na_2SO_4 and Na_2CO_3) on Fe, Co, Ni, Fe-Cr, Co-Cr surfaces, and the resulting dependencies of the solubilities of oxides (NiO, CoO, Al_2O_3, Cr_2O_3) on the salt chemistry is under investigation. Specially designed high temperature electrochemical probes are used to characterize the acid-base chemistry and the corrosion potential beneath thin salt films. Typical gaseous environments are CO_2, CO and O_2. For each salt system, cyclic voltammetry and A.C. (alternating current) impedance measurements are made as a function of salt thickness. Combinations of electrochemical, chemical, kinetic and morphological studies are employed to delineate the mechanisms of hot corrosion. Since a thin salt film supporting a gradient in basicity and oxygen potential also experiences an electrical potential gradient, analyses are underway to understand the role of this gradient in mobilizing charged solutes in the film. This is the first year of a three-year continuing grant, extending research previously supported under NSF Grant DMR79-11910 A02.

85. Emulsification and Undercooling of Pure Metals and Alloys

Current Award: 52.7/12/3CR
Effective Date: 7/1/82

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This is an experimental study on emulsification of pure metals and alloys in fused salts and their undercooling to crystal nucleation. An ultrasonic emulsification procedure will be utilized to prepare stabilized metal droplet emulsions. Fused salts will be used as a carrier fluid for droplets of metals and alloys which melt below 1100°C. The ultrasonic technique has been demonstrated to yield stable droplet dispersions like those previously shown to permit large undercoolings for metals with melting points below 450°C. The maximum undercooling to nucleation will be determined by differential thermal analysis. The crystallographic structure solidified at high undercooling will be determined by x-ray diffraction. The character of the emulsified droplets as solidified and cooled will be determined by scanning electron and optical microscopy. This study will employ the droplet technique to study the following liquid-solid reactions: nucleation of pure metals in undercooled liquid metals and alloys, formation of solid solutions, and the nucleation of stable and metastable compounds from the melt. The following pure metals and binary alloys systems will be included in the research program: Al, Ge, Ag, Cu, Au, Al-Ge, Al-Cu, Ag-Bi, and Au-Sb. The results of this study are expected to: (i) permit an assessment of the opportunities for use of the droplet emulsion technique at high temperatures; and (ii) improve understanding of the reaction path followed during undercooling, nucleation and solidification of metals and alloys. This is a continuation of research, previously supported under NSF Grant DMR81-07117 A01. This is the second year of a three-year continuing grant.

86. Basic Mechanisms of Sliding Friction and Wear

Current Award: 106.9/12/3CR
Effective Date: 4/1/82

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This is a fundamental study of mechanisms involved in sliding friction and wear. The materials systems to be investigated include Cu-Be (age-hardening system), Cu-Al_2O_3 (dispersion-hardened systems), dual phase steels (for fatigue correlations), dilute aluminum alloys, and coated systems (e.g., Cd or Sn or Cu). The friction model developed previously will be extended so that it can be easily used with experimentally determined stress-strain curves. Worn samples and debris will be studied with the aid of a wide range of analytical techniques, including microhardness tests, x-rays, scanning transmission and scanning transmission electron microscopies, and energy dispersive x-ray analysis. Planning of the experiments and analysis of the results will be guided by the predictions resulting from the energy-based model of friction, and by recent results on the relation of the accumulation of transfer material to both friction and wear. This research was previously supported by NSF Grant DMR78-05719 A02. This is the first year of a three-year continuing grant.

87. Interfacial Controlled Deformation and Fracture Mechanisms in Two-Phase Alloys

Current Award: 48.0/12/3CN
Effective Date: 11/1/81

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This research program consists of a microscopic structural and chemical analysis of interfacial-controlled deformation and fracture mechanisms. Iron-nickel and iron-chromium-nickel alloys, with and without trace impurities, were selected because their duplex austenite: ferrite microstructures allow analysis of grain boundaries and partially coherent interphase boundaries in a single specimen. Experimental techniques to be employed in this investigation include: high-voltage transmission electron microscopy (TEM) for in-situ analysis of interfacial deformation/crack nucleation/crack propagation mechanisms; high-resolution TEM and computer modeling for analysis of grain and interphase boundary structure; and scanning Auger microprobe and analytical electron microscopy for analysis of interfacial chemistry. The primary objectives of this research are: (i) to determine direct correlations between the interfacial structure and the interfacial segregation of matrix and/or trace impurity elements at partially coherent interphase and grain boundaries; and (ii) to relate microscopic deformation mechanisms (the initiation of slip at and propagation of slip through an interface) to interfacial structure and chemistry. This program should provide new insights into the nature of interfaces and into the roles that interfacial structure and chemistry play in the technologically important areas of deformation and fracture. This is the second year of a new three-year continuing grant.

88. Defect Aggregation in Irradiated Materials

Current Award: 76.7/12/3CR
Effective Date: 1/15/82

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Irradiation adds a fascinating and technologically important variable to materials research by moving the system into the relatively unexplored world of irreversible thermodynamics, where equilibrium thermodynamics are inapplicable. In addition to being of scientific interest, irradiation induced effects are of vital technological importance in ion-irradiation surface treatments, including ion implantation, and in the design of advanced reactor systems, in particular the controlled thermonuclear reactor and the breeder reactor. Irradiation induced voids and phase instability constitute major concerns in the development of both reactors. Research is underway in the area of phase stability and void nucleation. The focus of the research is a combined experimental and theoretical study of phase stability in ion-irradiated austenitic Fe-Ni-C alloys. An attempt is being made to induce precipitation of graphite in nominally undersaturated alloys; theory indicates such precipitation should occur. In addition, a thorough investigation is being made of the effects of irradiation on precipitation of graphite and cementite (and any phases unique to irradiation) over a range of conditions. The experimental program is complemented by a modeling study. This research is in cooperation with the Westinghouse Research and Development Center, which has performed a large number of dual-ion irradiation experiments. This is a continuation of research previously supported under NSF Grant DMR77-23402 A02. This is the second year of a three-year continuing grant.

89. Thermodynamic Modeling of Ternary Alloys

Current Award: 59.4/12/3CN
Effective Date: 8/1/82

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In recent years, the quantitative description of phase diagrams for simple alloy models has been considerably improved through the use of the Cluster Variation Method (CVM). At the same time, it has become increasingly clear that the commonly used phenomenological models for the atomic interactions must be modified in order to describe real systems. This is a systematic study of ternary alloys using CVM, with primary emphasis placed on the development of realistic phenomenological energy models in terms of concentration dependent pair and many-body interactions. Accurate free energy approximations will be used in order to obtain a complete thermodynamic description of prototype fcc and bcc ternary systems. In particular, equilibrium and metastable phase diagrams will be calculated. A detailed study will be undertaken for the NiAlCr and NiFeCr ternary systems. The required energy parameters for the phase diagram computations will be obtained from existing binary and ternary phase equilibrium data. The investigation of the complex NiAlCr and NiFeCr systems is expected to provide definite answers concerning the applicability of the CVM to real alloys. Finally, the accurate characterization of pair correlations by the CVM will be used to extract pair and many-body interactions from measured short-range order intensities. Initially, the intensity calculations will be carried out for the NiFe system. This is the first year of a new three-year continuing grant.

90. Diffraction Studies of Grain Boundary Structures in Face-Centered-Cubic Materials

Current Award: 109.1/12/5CR(C.E.)
Effective Date: 12/1/81

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This is an x-ray diffraction investigation of the structure of large angle grain boundaries in face-centered-cubic (fcc) metals. During the previous funding period, an x-ray technique was developed to measure the thickness of the grain boundary (g.b.) region, electron diffraction techniques were developed to study the g.b. of polycrystalline materials, and the atomic structure of twist and tilt boundaries was determined. These techniques are now employed to determine: (i) large g.b.'s in Au, Ag, Pt, Pd, Cu, Ni, and Al; (ii) g.b. thickness and its relationship to boundary structure; (iii) the effect of alloying on the structure of g.b.'s; (iv) the effect of segregation of solute atoms on g.b. structure; and (v) structure of g.b.'s as a function of temperature, to find evidence for the postulated grain boundary phase transformation. Several of these studies are now done using the Cornell High Energy Synchrotron Source. This is an extension of research, previously supported by NSF Grant DMR76-24180 A02. This is the third year of a three-year continuing grant. This project was recently awarded a two-year extension for Special Creativity.

91. Coal Gasification Kinetics in a Jet-Fluidized Bed

Current Award: 83.6/12/3CN
Effective Date: 6/1/82

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This is a fundamental investigation of reaction rates and rate-controlling variables for gasification of coal char with O_2, N_2, CO_2 mixtures in a laboratory scale jet-fluidized reactor. Jet fluidization is a new process in which fluidization and intensive gas-solid mixing are accomplished by directing a high velocity gas jet downward toward the center of a solid-bottom reactor vessel. This process greatly extends the levels of local suspension velocities and turbulence as compared to conventional fluidized beds, so that a quantitative kinetic model should be of both fundamental and practical interest. The jet fluidized reactor to be constructed for this work will be about 10cm. diameter by 100cm. height, with a water-cooled lance and other improvements over previous reactors to provide greater flexibility and longer periods of sustained steady operation. Overall reaction rates in steady state combustion and gasification runs under varying conditions will be derived from materials balance data. Thus, the data will provide the basis for calculating the apparent reactivity of the char, k, as grams C reacting/gram C in reactor-second-atmosphere CO_2 or O_2. These apparent reactivities will be compared with other reactivity data and predictions from mass transfer calculations to assess rate-controlling steps at various temperatures and to develop a valid kinetic model for jet fluidization. This is the third year of a new three-year continuing grant.

92. Structure and Strength of Spinodal Alloys

Current Award: 57.2/12/3CN
Effective Date: 1/1/82

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This is an investigation of strengthening mechanisms operative in spinodal alloys. Small angle neutron scattering from single crystals of Fe-Cr is used to characterize the coarsening stages of the decomposition. Mechanical behavior studies (yield stress, work hardening and response to cyclic deformation) are underway on alloys of Cu-Ni-Fe. These experiments on long wavelength materials complement the continuing studies of Cu-Ni-Sn. Advanced scattering and mechanical behavior experiments are underway, and theoretical studies have been initiated to explain the observed high yield strengths in these spinodal alloy systems. This is a continuation of research previously supported under NSF Grant DMR76-22995. This is the third year of a three-year continuing grant.

93. Kinetics of Diffusion Reactions in Coating Systems

Current Award: 66.0/12/3CR
Effective Date: 4/15/82

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This is a fundamental study of high temperature diffusional reactions operative during the formation and degradation of oxidation and sulfidation resistant coatings (e.g., aluminide, NiCrAlY) used to protect high temperature structural alloys. For the binary Fe, Ni and Co alloys with Al, chemical diffusivities in the phases FeAl (β_2) and CoAl (ζ) will be determined in the vicinity of the stoichiometric compositions. In the ternary system Ni-Cr-Al, chemical diffusivities will be determined over the composition range 0-50 atom percent (a/o) Al and 0-25 a/o Cr and the temperature range 800-1100°C. The diffusivity data will be used to study the kinetics of pack aluminization of Fe, Co and Ni-Cr substrates in order to extend the gas-solid diffusion theory of this process, and to test its applicability to more complex substrates. The mechanism of coating degradation by coating substrate interdiffusion will be modeled, using diffusivity data for the binary Fe-Al and Co-Al, and ternary Ni-Cr-Al systems. It is expected the results of this research will extend understanding of the dynamic nature of diffusional reactions underway in high temperature protective coating systems. This is a continuation of research, previously supported under NSF Grant DMR76-22018 A01. This is the second year of a three-year continuing grant.

94. Toward A Unified Theory of Morphological Stability

Current Award: 79.4/12/5CR(C.E.)
Effective Date: 1/1/82

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The theory of morphological stability is concerned with the stability of the interface shape which separates two or more phases during a phase transformation. The goal of this project is to unify and apply the theory of morphological stability to characterize solid-solid phase transformations, and to describe complex growth behavior in metallic systems. More specifically, experimental studies on ice disc thickening will be completed, and the theoretical framework developed will serve as a basis to describe complex faceted growth from liquid or solid solution. Theoretical and experimental studies on growth and morphological stability in solid-solid phase transformations is focusing on coupling strain effects with transformation kinetics, and on the influence of neighboring growth centers on the kinetics and morphology of a given precipitate. This is the fourth year of a five-year continuing grant. The fourth and fifth years of this project are supported under a two-year extension for Special Creativity.

95. The Kinetics of Formation and the Electrical Conductivity of Iron Carbide

Current Award: 71.9/12/3CN
Effective Date: 7/1/82

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This is a fundamental study to determine the kinetics of formation of iron carbide (Fe_3C) as a function of temperature (300° to 500°C) and carbon activity a_c (from the value of a_c in equilibrium with Fe-Fe_3C to a_c of 20). An automatic recording microbalance will be used for the growth kinetics of Fe_3C on thin iron films. Carbon will be deposited from methane gas/hydrogen gas mixtures at temperatures below 500°C. From the kinetic data, diffusivities of carbon in Fe_3C will be deduced as a function of carbon activity and temperature, and the results will be extrapolated to higher temperatures. These data will be used to elucidate the point defect structure of Fe_3C. Electrical conductivity measurements will be made on hot pressed samples of the carbide. If it is found that Fe_3C is a semiconductor, these data will be useful in determining the point defect structure of this compound. It is expected the results of this investigation will contribute significantly to knowledge about the properties of iron carbide. This is the first year of a new three-year continuing grant.

96. Concentration Dependence of Hydrogen Isotope Electromigration in Tantalum

Current Award: 41.7/24/2N
Effective Date: 6/15/80

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This is a fundamental investigaton of the behavior of the effective valence (Z^*) of hydrogen in tantalam at low hydrogen concentrations. The tasks underway include: (i) unambiguous determination of change in Z^* (i.e., positive to negative) as the hydrogen concentration is decreased; (ii) measurement of isotope effects in Z^* at these concentration levels in order to determine if Z^* for a particular isotope depends on the total hydrogen isotope concentration or on the concentration of that specific isotope; and (iii) determination of the effect of electric field on the observed Z^*. A combination of steady-state methods and techniques is used to measure directly the transport velocity. This is the second year of a new two-year grant.

97. Atom Probe Field Ion Microscopy Studies of Continuous Transformations in Alloys

Current Award: 140.8/12/3CN
(70.4 from Metallurgy and 70.4 from IUC)
Effective Date: 6/1/82

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The goal of this joint industry/university cooperative research program is to characterize and explain atomic events underway during continuous phase transformations in precipitation hardening systems. Materials being studied include Fe-Be, Cu-Ti, and Cu-Ni-Sn alloys. Some of these alloys decompose by a spinodal decomposition. It is expected that the results of this investigation will provide detailed information about the movement of atoms during a continuous phase transformation. The experimental observations should also clarify a number of scientific questions about the transformations which cannot be resolved in any other way such as the nature of the migrations of the individual atoms. This is the second year of a new three-year continuing grant.

98. The Strength and Fatigue of Precipitation-Hardened Alloys Strengthened by Modulated Structures

Current Award: 52.4/12/3CN
Effective Date: 7/15/82

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This is a fundamental study of flow and fracture behavior of Cu-Ti single crystals, and polycrystals of Cu-Ti and Cu-Ti-Cr strengthened by periodic arrays of coherent particles or long-range compositional modulation. Studies of monotonic deformation are coupled with experiments of cyclic stress-strain behavior in the low cycle regime, and of the Bauschinger effect. The results of this research are expected to define the detailed characteristics of the operational strengthening mechanisms in these alloys, and to determine what specific features of the modulated structures can be exploited in alloy design to achieve enhanced fatigue resistance. This is a continuation of research, previously supported under NSF Grant DMR76-81347. This is the third year of a three-year continuing grant.

99. Relationship Between Corrosion of Stainless Steels and Electrochemical Methods

Current Award: 120.0/12/3CN
Effective Date: 7/1/82

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Electrochemical measurements are widely used in the study of general, pitting and intergranular attack on austenitic and ferritic stainless steels and nickel-base alloys. However, because of the incomplete understanding of the relationship of these measurements to corrosion processes, there is a need for further investigations in order to make effective use of the electrochemical data for the study of corrosion mechanisms, alloy development and the prediction of performance of alloys in plant service. This program is a study of: (i) the time factor in potentiostatic measurements of pitting and intergranular attack; (ii) the differences between electrochemical, potentiostatic etching and simple immersion corrosion in detecting the presence of structural differences (carbide and nitride precipitates, intermetallic phases, submicroscopic units and equilibrium segregation);

(iii) the use of polarization measurements for defining the direct and synergistic action of alloying elements, Cr, Ni, Mo, in providing resistance to general corrosion in oxidizing and reducing acids and chloride environments; and (iv) the factors in the corrosive solutions which determine the corrosion currents on specimens under potentiostatic control as compared with those which determine corrosion in simple immersion tests at the same time electrode potentials. This is the third year of a new three-year continuing grant.

100. Micromechanisms of Hydrogen Cracking in Structural Steels

Current Award: 82.2/12/3CN
Effective Date: 7/1/82

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This is an investigation of micromechanisms of hydrogen cracking in structural materials. The emphasis is on the role of microstructure in hydrogen-induced fracture; both crack initiation and crack propagation behavior will be studied. Crack initiation studies will employ a bluntly-notched specimen to permit variation of applied stress at a distance which is large compared to the scale of the microstructure. Crack propagation will be studied under sustained load. The critical stress for cleavage in both normalized and pearlitic microstructures of steel will be measured, to determine whether and under what circumstances this stress is affected by hydrogen. Both bainitic and martensitic microstructures will be studied in a 9Ni steel; microstructural nuclei (predominantly second-phase particles) and fracture paths will be examined in detail, both with and without hydrogen. Results from both parts of the study will be used to model the microstructural and mechanical variables in hydrogen cracking; that modeling would include a local fracture criterion. It is anticipated that the results of the proposed work will lead to better understanding of microstructural factors in hydrogen cracking of steels and thus should provide guidance for design and development of structural materials. This is an extension of research previously supported by NSF Grant DMR78-00723 A02. This is the first year of a three-year continuing grant.

101. High Temperature Creep, Stress Rupture and Crack Growth in Multiphase Alloys

Current Award: 76.2/12/5CR(C.E.)
Effective Date: 4/15/82

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This is a fundamental investigation on creep and stress rupture behavior of particle-strengthened high temperature metallic materials (i.e., gamma-prime superalloys and oxide dispersion strengthened nickel-base alloys). Research underway extends previous creep and stress rupture studies to cyclic loading. The particle strengthened high temperature alloys may exhibit a wide range of cyclic creep behavior due to complex strain relaxation arising from the many components of internal stress. More specifically, studies underway include: (i) internal stresses at creep strain rates, including the particle threshold stress and the solid solution friction stress (to identify the residual stresses remaining after load removal); (ii) the role of particles in cyclic creep, contrasting alloy behavior with and without coherent gamma prime particles and/or with and without incoherent oxide particles; (iii) the role of dislocation network recovery in cyclic creep and stress rupture, correlating the cyclic creep results with static primary creep behavior; (iv) the role of grain boundary sliding in cyclic creep and stress rupture, using control of grain boundary carbides to select grain boundary sliding behavior; (v) effects of load cycling on tertiary creep and creep crack growth; and (vi) the effects of rare-earth additions on stress rupture behavior. This is a continuation of research, previously supported under NSF Grant DMR77-11281 A01. This is the third year of a three-year continuing grant. This research was recently approved for a two-year extension for Special Creativity.

102. Supermodulus Effect in Bulk Alloys

Current Award: 44.7/12/5CR(C.E.)
Effective Date: 6/1/82

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This is a fundamental investigation into the origin and nature of the supermodulus effect (i.e., enhanced elastic modulus in compositionally-modulated alloys). The objectives of this research include: (i) synthesis and fabrication of high elastic modulus bulk metallic materials; (ii) characterization/explanation of the supermodulus effect in bulk alloys; (iii) elucidating the role of applied stress field on spinodal decomposition; (iv) growth kinetics measurement of one-dimensional composition modulations in spinodal alloys; (v) determination of the effect of external stress field on the bulk elastic constants of spinodal alloys; and (vi) providing a theoretical explanation for the origin and nature of the supermodulus effect in thin and bulk specimens. Research underway includes: (i) advanced studies of elastic constants of Al-Zn single crystals, and Cu-Ni, Cu-Pd alloys; (ii) detailed studies of the supermodulus effect and solid state transformation behavior of a ternary system (Al-Zn-Cu), and of other ternary systems with coherent precipitates (i.e., Ni-base superalloys and Fe-Cr-Co spinodal alloys); (iii) advanced experiments to characterize the stability of concentration waves of binary and ternary modulated foils for the systems: Fe-Cr, Cu-Ni-Si, Cu-Ni-Cr, Cu-Ni-Fe, Fe-Cr-Co and Ni-Co; (iv) extension of studies of the "stiffening effect" of interatomic potentials by internal elastic strains produced by the lattice coherency; and (v) extension of the five point numerical scheme devised for the one-dimensional nonlinear differential equation in binary solids, to three dimensions, and development/inclusion of stability and conversion criteria to characterize the evolution of spinodal decomposition in the presence or absence of externally applied stress. This is the fourth year of a new five-year continuing grant. The fourth and fifth years are supported under a two-year extension for Special Creativity.

103. Single Atom Interactions and Surface Segregation of Dilute Alloys Using Atom-Probe and Field Ion Microscopy

Current Award: 37.3/12/3CN
(18.5 from Metallurgy, and
18.8 from Solid State Physics)
Effective Date: 7/15/82

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The unique atomic resolution of the field ion microscope (FIM) is being used to investigate systematically the interaction between two atoms, both adatom-adatom and adatom-substrate atom interactions, on group VIII and IB surfaces. The atomic interaction is being correlated with the electronic structures of adatoms and substrate surfaces, and the directional walk of the single atoms under a controllable driving force is also being investigated. This information is not only of fundamental interest, but is also related to the surface reactivity. Since the unique catalytic activity of a surface arises partly from surface segregation of minority species in the alloy, the absolute composition depth profiles of near surface layers of dilute alloys are also being measured using the single atomic layer spatial resolution of the time-of-flight-atom-probe FIM. The dependence of the composition of near surface layers on the bulk concentration of minority species, the sample temperature, and the crystal planes is being investigated, as well as the kinetics of reaching thermodynamic equilibrium. The alloys chosen for this study are nickel-copper, platinum-gold and platinum-copper since they are accessible to FIM study and they also offer various tests of the existing theories. This is a supplement to the third year of support, of a new three-year continuing grant.

104. Effects of "Fast" Diffusing Impurities on Properties of Metallic Solid Solutions

Current Award: 51.0/12/3CR
(17.0 from Metallurgy, and
34.0 from Solid State Physics)
Effective Date: 9/1/82

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This research is directed mainly to the problems of: (i) the thermodynamics and kinetics of association of fast diffusing impurities in lead with special emphasis on the unexpected association of silver in the 175—300 K temperature range; (ii) the characterization of quench hardening in lead and lead alloys and its relation to dislocation loop content; and (iii) the interaction of vacancies and of vacancy clusters (presumably dislocation loops) with noble metal impurities in various association states and the effects of these interactions on the mechanical strength. In accord with these objectives, the positron trapping and annihilation studies, made in cooperation with Professor Berko, are being directed toward monitoring the formation of dislocation loops and their response to low temperature annealing. With these results it should be possible to conduct tensile tests on specimens in which both the dislocation loop content and the state of association of the impurity (from resistometric studies) are characterized. These tests should permit the quench and solute hardening effects in the alloys to be identified. This is a continuation of research, previously supported under NSF Grant DMR77-10151 A02. This is the third year of a three-year continuing grant.

105. Quantitative Evaluation of Fracture Surfaces by Stereological Analysis

Current Award: 82.4/18/3CN
Effective Date: 8/1/82

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The success as well as predictive capabilities of fracture theories are increasingly dependent on quantitative microstructural and fractographic parameters. However, of necessity, results are largely qualitative in nature because of the nonplanarity of the fracture surface. The goal of this project is to develop methodologies and relationships of general validity so that features of the fracture surface can be characterized quantitatively. A three part approach is adopted in this research program, consisting of experimental, analytical, and computer-based contributions. The experimental work uses Al-4% Cu alloys fractured in tension, and measurements are based on scanning electron microscope photomicrographs and vertical sections through the fracture surface. The analytical portion employs the basic equations of stereology and projected images to related microstructural and fractographic quantities. In addition, methods will be developed for the determination of fracture surface area from measurements made on fracture traces. The third part of the program involves a computer-simulated fracture surface of known characteristics which can be cut by randomly oriented or positioned sectioning planes. The computer program will be used to develop an optimized analytical expression for true surface area, and to indicate the minimum extent of sampling required to insure adequate statistical coverage for real fracture surfaces. This is the first installment on a new thirty-month continuing grant.

106. Structure, Composition and Thermal Properties of Solid Surfaces

Current Award: 33.6/12/3CR
Effective Date: 1/1/82

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This is a fundamental experimental study of the composition, structure and thermal properties of Pt and Mo surfaces, using the techniques of Rutherford Backscattering, Low-Energy Electron Diffraction and Nuclear Micro-Analysis. The objectives are: (1) to study atomic displacements at step edges; (2) to study correlated atomic vibrations on Pt surfaces; (3) to study atomic motions occurring during the (1 1) (2 2) reversible phase transition on Mo (100); (4) continue development of Nuclear Micro-Analysis as an analytical tool for surface composition determinations. The experiments are designed (1) to yield new information about atomic positions and motions and their role in the surface chemical properties of low index and stepped Pt surfaces; (2) to develop criteria for surface stability; (3) to improve the techniques to quantify surface compositions on an absolute scale. These experiments are being performed at the facilities of the Chalk River Nuclear Laboratories, Chalk River, Ontario, Canada, and in collaboration with the scientists there. This is a continuation of research previously funded under NSF Grant DMR77-28543. This is the second year of a three-year continuing grant.

107. The Structure of Liquid and Amorphous Metallic Alloys and the Structural Relaxation of Metallic Glasses

Current Award: 80.0/12/3CR
Effective Date: 6/1/82

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This is an investigation of the structure and structural relaxation of binary (and quasi-binary) amorphous alloys of Ti with Cu and Ni, and Zr(Hf) with Cu, Ni, and Mn in an effort to increase our knowledge of the fundamental nature of the atomic structure, i.e., the topological and chemical short-range order, and defects of the metallic amorphous state, and to compare it with the corresponding liquid state. Corollary goals are: 1) to correlate the foregoing with variations in critical properties resulting from primary fabrication and post-quenching annealing, and 2) ultimately to determine to what degree it may be possible to control and usefully modify physical properties by the annealing treatments. X-ray and neutron large-angle scatterinng are used to determine the total interference function and atomic distribution functions of these alloys in the liquid and amorphous solid states with differing degrees of disorder. The partial interference functions (or structure factors) and distribution functions are being evaluated from several scattering experiments. Isotope substitution (Ni, Cu, Ti isotopes), isomorphous substitution (Hf for Zr in x-ray experiments, and Co for Ni in neutron experiments), and anomalous dispersion are used to effect changes in the x-ray and/or neutron scattering cross-sections. Since natural Ti and Mn possess negative scattering cross-sections b for neutrons, it is possible to prepare alloys with $\langle b \rangle = 0$, which permits us to determine directly the chemical short-range order in the amorphous and liquid states. X-ray and neutron small-angle scattering are employed to investigate concentration and density fluctuations in the alloys. This is a continuation of research previously funded under NSF Grant DMR78-09929 A01. This is the third year of a three-year continuing grant.

108. Internal Stress in Class I Solid Solution Alloys

Current Award: 49.5/12/3CR
Effective Date: 6/15/82

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The goal of this project is to obtain answers about the basic mechanisms of the high temperature creep deformation of metals and alloys. In class I alloys, the presumed rate controlling mechanism of creep is the diffusional drag of alloying atoms by dislocations. By decreasing the stress suddenly during a creep run, transients in the creep deformation are produced. A theory for such transients has been developed for class I alloys. If the creep transients that will be measured in an aluminum-copper alloy agree with the predicted ones, this agreement would add very strong support for the diffusional drag mechanism of the creep of class I alloys. In class II alloys and pure metals there has been a heated dispute whether in the temperature range of about 0.3 to $0.6T_m$, where T_m is the melting temperature of the material, the rate controlling process of creep is one that does not involve diffusion or is a self-diffusion controlled motion of dislocations. Measurements of the subgrain misorientation in tin specimens and other metals will make it possible to decide between these competing creep mechanisms. The first mechanism requires that the subgrains in a metal have misorientation angles of the order of the creep strain while the second predicts that the misorientation angles are orders of magnitude smaller. Internal stress measurements are underway on single-phase Al-rich Cu alloys at three compositions, extending the concentration range already completed, as a function of temperature and pressure. In addition, larger grain specimens have been prepared to verify earlier results, which demonstrated that the internal stress is grain size independent at larger grain sizes. Lastly, the theory developed will be tested on two other alloy systems (ordered βCu-Zn and the Pb-Sn system). This is a continuation of research, previously supported under NSF Grant DMR77-12670. This is the third year of a three-year continuing grant.

109. Small Angle Neutron Scattering Study of the Initiation and Early Growth Behavior of Grain Boundary Voids

Current Award: 45.7/12/5CR(C.E.)
Effective Date: 12/1/81

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This is a fundamental investigation into the mechanisms responsible for grain boundary cavitation (i.e., grain boundary void formation and growth) during high temperature fatigue and creep. A model material, 99.999% pure copper, is used in this investigation. The void formation and growth are measured by small angle neutron scattering techniques (SANS). The rate of void formation and growth are measured as a function of temperature, stress, frequency and cycle shape. These data are analyzed and compared directly with those predicted by the various models. Current emphasis is on use of SANS to determine the temperature and stress dependence of cavity growth during creep of metallic materials containing controlled amounts of prenucleated voids. From scattering data, cavity growth rates are computed for specific conditions of creep. It may be possible to determine creep nucleation rates, if the increase in void number generated during creep is detectable. Results obtained will be compared with existing theories of creep cavitation, whenever possible. However, most theories of creep are based upon time-independent loading, whereas creep is a time-dependent phenomenon. This is a continuation of research, previously supported under NSF Grant DMR75-20365 A01. This is the fourth year of a five-year continuing grant. The last two years of this grant are supported under a two-year extension for Special Creativity.

110. Effect of Slip-Mode in Oxygen-Rich Titanium Alloys on Monotonic and Cyclic Deformation Behavior

Current Award: 91.4/12/3CN
Effective Date: 6/15/82

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This is a fundamental investigation of the mechanical behavior of oxygen-rich titanium alloys. Specific research objectives include: (i) evaluation of slip modes in the alpha-phase of a titanium alpha/beta alloy as a function of oxygen concentration and aging, and the relative role of oxygen in effecting the change from prismatic slip predominance to pyramidal slip; (ii) determination of the range of applicability of specific modes in monotonic and cyclic deformation; (iii) assessment of a hypothesis concerning fatigue damage accumulation consisting of vacancies or vacancy clusters as a function of slip mode in the alpha-phase, and; (iv) characterization of the deformation mode(s) of the beta-phase and the slip interaction at alpha/beta interfaces in each lamellar and equiaxed material. The model material (characteristic of titanium alpha/beta alloys) under study is Ti-6Al-4V. A few specimens of a more complex system (Ti-6Al-2Nb-1Mo-1Ta) will be studied to assess the generality of the research results. Experimental methods will include monotonic and cyclic deformation, transmission and analytical electron microscopy, positron annihilation and other mechanical characterization techniques. The mechanical behavior will be determined in light of the slip modes in alpha, in beta, and the interactions of alpha and beta phases in the lamellar and equiaxed microstructures. This is the first year of a new three-year continuing grant.

111. The Role of Structure in the Wear Process

Current Award: 60.0/12/3CR
Effective Date: 7/15/82

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This is a fundamental study on the effect of specific microstructural parameters (i.e., stacking fault energy, degree of chemical order, and lattice instabilities—such as displacive phase transformations and grain boundaries) on mechanisms of wear of metallic materials. There are two approaches to this research: (i) microscopic determination of the lattice defect structure and distribution on lightly surface deformed specimens, using analytical and high voltage electron microscopy; and (ii) macroscopic-direct correlation of the microscopic observations with material loss rates during wear and coefficient of friction measurements on identical materials. The materials under study include Cu-Al, Fe-Ni and Fe-Mn alloys. It is expected the results of this research will lead to an understanding of wear mechanisms of metallic materials, and serve as the basis for the synthesis of wear-resistant alloys. This is a continuation of research, previously supported under NSF Grant DMR78-11394 A01. This is the third year of a three-year continuing grant.

112. Quantitative Microstructural Characterization of Aluminum-Lithium Based Alloys

Current Award: 46.2/12/3CR
Effective Date: 7/1/82

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Aluminum-lithium based alloys are potentially of great engineering interest because they offer high strength and good fatigue and corrosion resistance, while weighing significantly less than current commercial aluminum alloys due to the low density of lithium. However, poor ductility and toughness limit applications of these alloys. This is due to lack of knowledge of the reactions in the alloys that are responsible for the attractive properties. The aim of this research is to seek further understanding of the characteristics of the δ' (Al_3Li) phase which accounts for both the high strength and poor toughness of the alloys. Specifically, attempts will be made to manipulate the structure of the interface between the δ' phase and the aluminum matrix so that localized deformation will not occur, thus improving the toughness. Also, basic phase diagram information will be sought and attempts will be made to produce desirable distributions of δ' using the existence of a coherent solvus in Al-Li alloys, previously documented by the principal investigator. The approach to the problem outlined above will consist of the the addition of controlled amounts of ternary elements to Al-Li alloys. The effects will be studied using analytical electron microscopy and both the structure and chemistry of the phase will be defined as a function of ternary additions. This is a continuation of research previously supported under NSF Grant DMR79-23278. This is the second year of a three-year continuing grant.

113. Hot and Warm Deformation of an Ordered, Limited-Slip Polycrystal

Current Award: 73.0/12/3CR
Effective Date: 2/1/82

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Previous work has set forth stress-strain rate-temperature interrelationships and fracture behavior in superconducting A15 polycrystals, primarily Nb_3Sn and V_3Ga. Interpretation of this behavior requires rigorous diffusion data. Moreover, while cubic slip and "power law" creep behavior have been clearly set forth, polycrystalline deformation requires more than the three independent slip systems of cubic slip; possibilities such as non-cubic slip and gross climb must be investigated. Hot deformation (above $0.6T_{solidus}$) does not affect T_c, whereas ambient temperature deformation splits and/or broadens T_c (with sharp T_c behavior being restored with an anneal). Thus, deformation studies in the "warm" range (about $0.5T_{solidus}$) are needed to explore possible causative factors such as lattice disordering. Such studies will allow evaluation of fine grain size material as well and will address conditions of conductor processing. The objectives of the proposed work are: (i) measurement of bulk and grain boundary diffusion coefficients for Nb and Sn in Nb_3Sn in the 900 to 1650°C range (interpretation of mechanical behavior and Nb_3Sn formation behavior in light of the diffusion data); (ii) determination of micromechanisms of high temperature A15 deformation through etch pit studies, slip band analysis (if possible), as-deformed grain morphology analysis, and more rigorous preservation of defect structures for microscopic analysis; and (iii) extension of Nb_3Sn mechanical studies to the "warm" deformation range of 950°C, inclusive of testing of specimens of refined grain size and study of effects on T_c, long range order, and dislocation configuration. This is a continuation of research previously supported under NSF Grant DMR78-05726. This is the second installment on a thirty-month continuing grant.

114. Nonlinear Anelasticity of Metals and Alloys

Current Award: 95.9/12/5CN(C.E.)
Effective Date: 6/15/82

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Deformations created by moving interfaces are coherent and finite, as are deformations created by martensitic transformations. The goal of this study is to understand the kinetics of deformation-induced moving interfaces in general, and their relationship to characteristics/mechanisms operational during martensitic transformations. Automodulations (i.e., superposition of large amplitude displacements with long periods) occur in samples which undergo martensitic transformations. Internal friction techniques are being used to characterize these phenomena on Cu-Zn-Al, Cu-Ni-Al, Cu-Au-Zn, and Cu-Au alloys. The results of these measurements provide higher order unrelaxed and relaxed elastic constants, and delineate the time evolution of the martensitic transformation. Emphasis is currently placed on understanding the role of specific intrinsic and extrinsic point defects in controlling the time evolution of twinning, and the formation of martensite in hexagonal close-packed metallic systems. This is the fourth year of a new five-year continuing grant. The fourth and fifth years of this project are supported under a two-year extension for Special Creativity.

115. The Relationship Between Surface Structure and Equilibrium Surface Structure in Alloys

Current Award: 73.0/12/3CN
Effective Date: 3/1/82

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This is a study to systematically evaluate the effects of surface structure on surface composition. In the first part of the study, the surface structure of macroscopic alloy crystals of the Ni-Au and Ni-Pd systems will be modified so as to produce all three of the basic structural units of extended surfaces, namely: terraces, steps and kinks. The effects of these structural units on surface composition will be established by direct measurements using Auger electron spectroscopy (AES) and low energy electron diffraction. In the second part of the study, surface structure will be changed by producing very small alloy particles, again of Ni-Au and Ni-Pd, so as to modify the relative numbers of corner, edge and face sites. The effects of those structural units on surface composition will also be evaluated experimentally by AES. Particle sizes and shapes will be evaluated by transmission electron microscopy. The third and final part of the study will develop a better theoretical description of surface segregation phenomena by reassessing several aspects of current segregation formalism. This is the first year of a new three-year continuing grant.

C1. International Conference on Electron Beam Interactions with Solids for Microscopy Microanalysis and Microlithography

Current Award: 5.0/12/CONF
Effective Date: 2/15/82

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This grant provides partial support for this international conference, which will serve as a forum for discussion of theoretical and experimental advances and future research needs. The topics to be covered include: (i) fundamentals of electron beam interaction with solid targets (including elastic and inelastic cross sections; backscattered, secondary and Auger electrons, electron-hole pairs, and x-ray production; electron loss spectroscopy); (ii) modelling of electron beam interactions with solid targets including analytical methods (using backscattered electrons and depth distribution of ionizations), Monte Carlo methods, transport equation methods and electron channeling; and (iii) applications of electron-beam interactions with solid targets including radiation effects in materials, fundamental limits in electron lithography, and signal-detector strategy. Proceedings of this conference will be published.

E1. Acquisition of an X-Ray Pole Figure Facility

Current Award: 20.0/12/E
Effective Date: 10/1/82

B. Adams[1] *and G. Onada*[2]
Dept. of Materials Science & Engineering
University of Florida
Phone: [1](904)392-1457
[2](904)392-1455

This grant provides partial funding toward the purchase of an x-ray pole figure facility, for use with an existing high flux micro-x-ray diffraction facility. It will be used to characterize preferred orientation of metallic, ceramic and polymeric materials on numerous, on-going research grants.

E2. Acquisition of a Scanning Electron Microscope

Current Award: 80.0/12/E
Effective Date: 7/1/82

R.J. Bayuzick
Dept. of Mechanical & Materials Engineering
Vanderbilt University
Phone: (615)322-2241

This grant provides partial support toward the purchase of a replacement analytical scanning electron microscope with wave length dispersive system and accessories. This system is necessary to enhance the capability to perform microchemical and structural analyses on a variety of materials, for numerous on-going materials research projects spanning many disciplines. This system will be used in a central facility mode of operation.

E3. Acquisition of Mechanical Testing Equipment

Current Award: 23.0/12/E
Effective Date: 3/15/82

H.K. Birnbaum
Dept. of Metallurgy & Mining Engineering
University of Illinois at Urbana
Phone: (217)333-1901

This grant provides partial funding for the purchase of a closed loop servo hydraulic mechanical testing facility. The equipment is required to continue on-going hydrogen embrittlement studies of metallic materials. The equipment will replace a non-functional, non-repairable twenty year old system.

E4. Acquisition of a Scanning Electron Microscope-Electron Microprobe

Current Award: 145.0/12/E
(110.0 from Metallurgy, 20.0 from Ceramics, and 15.0 from Polymers)
Effective Date: 12/15/81

J.R. Blachere
Dept. of Metallurgical & Materials Engineering
University of Pittsburgh
Phone: (412)624-5296

This grant provides partial funding for the purchase of an integrated scanning electron microscope-electron microprobe system. The system will be used in central facilities mode of operation, for structural and microchemical anlayses on numerous materials projects including research on high temperature metallic corrosion and oxidation, mechanical properties of metals, ceramics and polymers, and casting and solidification of metallic materials.

E5. Acquisition of X-Ray Diffraction Equipment for Materials Research

Current Award: 44.2/12/E
(29.2 from Metallurgy, and 15.0 from Ceramics)
Effective Date: 6/15/82

S.H. Carpenter[1] *and P.K. Predecki*[2]
[1]*Dept. of Physics & Astronomy*
[2]*Dept. of Chemistry*
University of Denver
Phone: (303)753-2176

This grant will provide partial support toward the purchase of an x-ray diffractometer retrofit system and ancillary components to modernize the current x-ray diffraction system. The equipment is necessary to obtain structural information on atomic arrangements of metallic, ceramic, composite and polymeric materials, on numerous federally-sponsored materials research projects. The updated instrumentation will be properly maintained and used in a central-facility mode of operation.

E6. Acquisition of Data Collection System for Surface Analysis Facility

Current Award: 24.4/12/E
Effective Date: 12/15/82

C.R. Clayton
Dept. of Materials Science & Engineering
State University of New York at Stony Brook
Phone: (516)246-3391

This grant provides partial funding for a data system and modular interface for use with an existing X-ray-Photoelectron Spectroscopy (XPS) and Scanning Auger Microscopy (SAM) system. This equipment will be used in supportive mode for ongoing materials research programs in need of elemental and chemical characterization of surfaces.

E7. Acquisition of X-Ray Diffractometer System

Current Award: 32.5/12/E
Effective Date: 8/1/82

R.J. De Angelis
Dept. of Metallurgical Engineering & Materials Science
University of Kentucky
Phone: (606)257-2738

This grant provides partial support toward the purchase of an x-ray diffraction system, ancillary electronic components, and a computer system. The system will be used in a central-facility mode for structural characterization of metals, polymers, organic and organo-metallic materials, on active projects underway in several departments.

E8. Acquisition of an Electron Microprobe

Current Award: 60.0/12/E
(30.0 from Metallurgy, and 30.0 from MRL Section)
Effective Date: 7/1/82

M.S. Dresselhaus
Materials Research Laboratory
Massachusetts Institute of Technology
Phone: (617)253-6864

This grant provides partial support for the acquisition of an electron microprobe within the Center for Materials Science and Engineering (CMSE). This high resolution instrument will have the capability for quantitative compositional analysis of low atomic number elements, and includes an x-ray microanalyzer with wavelength and energy dispersive capabilities. The instrument will be part of a new electron microanalyzer central facility within CMSE, and be used for research on grain boundaries, fine grained separation, welding reactions, polymer coatings, superconducting composites, corrosion products, crystallization of glasses, semiconductor heterostructures, and electrode materials.

E9. Acquisition of Instrumentation for Rotating Anode X-Ray Generator

Current Award: 80.0/12/E
Effective Date: 7/1/82

P. Ehrenreich
Materials Research Laboratory
Harvard University
Phone: (617)495-3213

This grant provides funding for a second port on a rotating anode x-ray generator. It will be used for on-going research on studies of free surfaces of liquid metals, effect of structural relaxation on the structure factor of metallic glasses, structural characterization and crystallization of metallic glasses, and amorphous metallic films with compositional modulation.

E10. Acquisition of a Particle Size Analyzer

Current Award: 16.0/12/E
Effective Date: 6/15/82

R.M. German
Dept. of Materials Engineering
Rensselaer Polytechnic Institute
Phone: (518)270-6371

This grant will provide partial support toward the purchase of a particle size analyzer and ancillary components. The equipment is necessary for characterizing particulates (i.e., particle size and distribution) of metallic and ceramic powder on numerous on-going research projects.

E11. Acquisition of an Electron Probe Microanalyzer

Current Award: 125.0/12/E
(100.0 from Metallurgy, and 25.0 from Ceramics)
Effective Date: 6/15/82

J.I. Goldstein[1] *and D.B. Williams*[2]
Dept. of Metallurgy & Materials Science
Lehigh University
Phone: [1](215)861-4208
[2]*(215)861-4224*

This grant provides partial support for the purchase of a replacement electron probe microanalyzer for non-destructive quantitative x-ray microchemical analyses of metallic, ceramic and polymeric materials on numerous on-going materials research projects. The instrumentation will be used in a central facility mode of operation.

E12. Acquisition of an Analytical Electron Microscope

Current Award: 234.1/12/E
(174.1 from Metallurgy, and 60.0 from Ceramics)
Effective Date: 7/1/82

P.R. Howell
Dept. of Materials Science & Engineering
Pennsylvania State University
Phone: (814)864-1288

This grant provides partial funding toward the purchase of an analytical electron microscope. This microscope will broaden considerably the scope of materials characterization now possible with electron optical facilities, to include high resolution imaging in the conventional transmission electron microscopy mode together with quantitative x-ray microanalysis, electron energy loss spectroscopy, and quantitative microdiffraction in the scanning transmission mode. The facility will be located in the College of Earth and Mineral Sciences, and will be used and maintained in a central-facility mode of operation on a broad range of active research programs on metallic, ceramic, electronic and geological materials.

E13. Acquisition of an Ion Milling Facility

Current Award: 17.5/12/E
Effective Date: 6/15/82

N. Jayaraman
Dept. of Materials Science & Metallurgical Engineering
University of Cincinnati
Phone: (513)475-3096

This grant provides partial support for the purchase of an ion milling facility for the preparation of thin foils for transmission electron microscopy investigations. The facility will be used to prepare metallic and ceramic materials for microstructural characterization, on several on-going studies of environmental degradation (i.e., oxidation and sulfidation) of high temperature structural materials.

E14. Acquisition of an X-Ray Diffractometer System

Current Award: 39.3/12/E
(26.3 from Metallurgy, and 13.0 from Ceramics)
Effective Date: 6/15/82

D.L. Johnson
Dept. of Mechanical Engineering
University of Nebraska
Phone: (402)472-3088

This grant provides partial support toward the purchase of an x-ray diffraction system which is needed for structural characterization of metallic and semiconducting materials on several on-going research projects.

E15. Acquisition of an Electron Beam Evaporation System

Current Award: 40.0/12/E
(20.0 from Metallurgy, and 20.0 from MRL Section)
Effective Date: 7/1/82

H.H. Johnson
Materials Science Center
Cornell University
Phone: (607)256-4272

This grant provides partial funding for a modern beam evaporation system. Although the immediate need is for research on grain boundaries of specific misorientation in metallic materials, the facility has broader use in the preparation of thin film metallic materials.

E16. Acquisition of Neutron Beam Guide Tubes for Small Angle Neutron Scattering Facility

Current Award: 50.0/12/E
Effective Date: 6/1/82

W.L. Koehler
Oak Ridge National Laboratory
Phone: (615)574-5232

This grant provides funds for the acquisition, fabrication and installation of neutron beam guide tubes at the Oak Ridge small angle neutron scattering facility. It will improve the available neutron flux on samples by a factor of five to ten.

E17. Acquisition of Scanning Electron Microscope

Current Award: 75.0/12/E
Effective Date: 7/1/82

BEST

W.W. Mullins
Materials Research Laboratory
Carnegie-Mellon University
Phone: (412)578-2541

This grant provides partial funding for the purchase of a scanning electron microscope. It will be used for surface topological and/or microstructural characterization on numerous research projects.

E18. Acquisition of an Integrated Mechanical Testing Facility

Current Award: 40.0/12/E
Effective Date: 6/15/82

W.D. Nix
Dept. of Materials Science & Engineering
Stanford University
Phone: (415)497-4259

This grant provides partial funding for the purchase of an electromechanical testing machine, and ancillary data acquisition and control systems. The equipment will be used for on-going research on the mechanical properties of materials.

E19. Acquisition of a Direct Reading Rapid Nitrogen Determinator

Current Award: 18.1/12/E
Effective Date: 7/1/82

H. Wada and R.D. Pehlke
Dept. of Materials & Metallurgical Engineering
University of Michigan
Phone: (313)764-7489

This grant provides partial funding toward the purchase of a direct reading rapid nitrogen determinator. It will be used for nitrogen analysis on active research projects in the area of high temparature gas-metal reactions.

E20. Acquisition of a Scanning Transmission Electron Microscope

Current Award: 202.0/12/E
(55.0 from Metallurgy, 32.0 from Ceramics, and 115.0 from Polymers)
Effective Date: 7/15/82

M.R. Plichta[1] and P.J. Phillips[2]
Dept. of Materials Science & Engineering
University of Utah
Phone: [1](801)581-5604
[2](801)581-8574

This grant provides for partial funding of the acquisition of a state-of-the-art scanning transmission electron microscope and various accessories. This instrument will be used primarily by materials science faculty and researchers, but also by faculty and researchers from several other departments in the College of Engineering, the College of Mines and Mineral Industries, and College of Science. Among the research projects in which the equipment will be used are those dealing with crystallization and morphology of polymers; interphase boundary structure in metallic alloys; phase transformations in ceramics; fracture processes in polymers and composites; and surface structure in catalysts. The new instrument will greatly extend the capabilities of the researchers at the University of Utah and replace inferior, old equipment now in use.

E21. Acquisition of a Universal Testing Machine

Current Award: 25.0/12/E
Effective Date: 10/1/82

D.P. Pope
Dept. of Materials Science & Engineering
University of Pennsylvania
Phone: (215)898-7977

This grant provides partial support for the purchase of a mechanical testing facility. The equipment will be used by a group of metallurgical faculty members on numerous on-going research programs, including studies on: plastic flow in pure metals and ordered alloys; intergranular fracture of iron-based alloys; and fatigue of metallic materials.

E22. Acquisition of a Scanning Transmission Electron Microscope for Chemical and Metallurgical Analysis

Current Award: 193.7/12/E
Effective Date: 7/1/82

D.I. Potter
Dept. of Metallurgy
University of Connecticut
Phone: (203)486-2816

This grant provides partial funding for the purchase of a scanning transmission electron microscope with ancillary equipment for chemical analysis using energy dispersive x-ray analysis. It will be used in a central-facility mode of operation for structural and chemical characterization of materials, on numerous on-going research projects.

E23. Acquisition of an Ion Beam Thinner

Current Award: 15.0/12/E
(5.0 from Metallurgy, 5.0 from Ceramics, and 5.0 from Geosciences)
Effective Date: 1/1/82

W.D. Scott
Dept. of Ceramic & Metallurgical Engineering
University of Washington
Phone: (206)543-2032

This grant provides partial funding for the purchase of an ion beam thinning mill for the preparation of specimens for

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observation in transmission electron microscopy. The instrument will be used for research on metallic, ceramic and geological materials on numerous projects, such as studies of fundamental deformation processes, and the synthesis of innovative classes of high temperature materials.

E24. Acquisition of a High Energy Ion Scattering and Ion Implantation Facility

Current Award: 70.0/12/E
Effective Date: 7/1/82

D. White
Materials Research Laboratory
University of Pennsylvania
Phone: (215)898-8571

This grant provides partial funding toward the purchase of a high energy 1MeV-9MeV ion scattering and ion implantation facility. The facility is needed to advance the study of surfaces on numerous on-going materials projects.

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Ag, Ag alloys
11, 63, 85, 90, 104

Al, Al alloys
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